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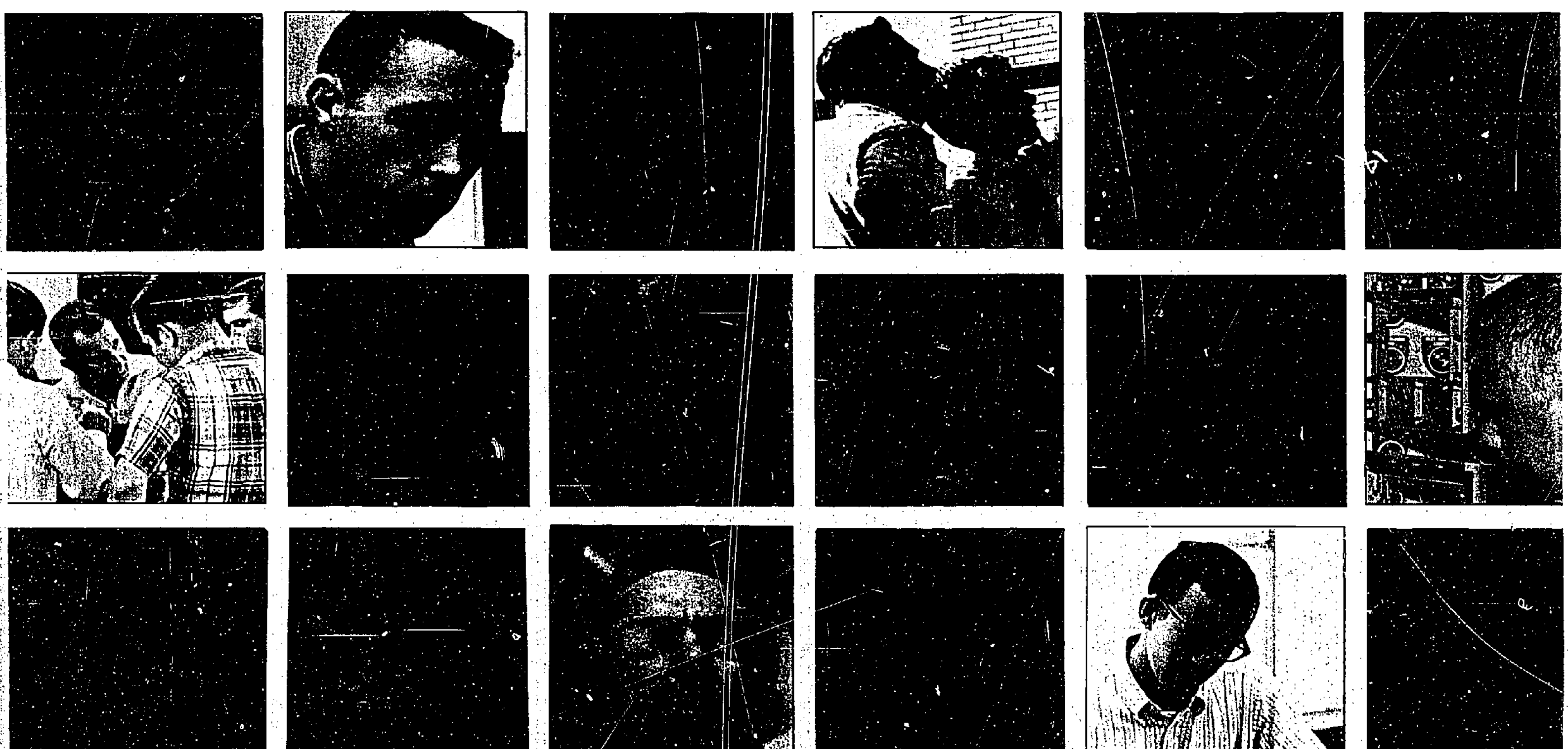
ABSTRACT

This is the half-way report of a 2-year study of engineering technology education that began in August 1969. The various sections include: (1) the history, traditions and transitions of engineering technology education; (2) abstracts of 4 important reports of technology education since 1960; (3) recent trends in the field; (4) goals, objectives, and broad features of engineering technology education; (5) characteristics that differentiate between engineering, engineering technology, and industrial technology education; (6) characteristics of associate degree curricula in engineering; (7) a survey of baccalaureate engineering technology; (8) recommended characteristics of baccalaureate engineering technology programs; (9) practical engineering versus engineering technology programs; and (10) human source material for engineering technology education. (HS)

Engineering Technology Education Study
PRELIMINARY REPORT

American Society for Engineering Education
October 15, 1970



...Comments on this preliminary document are earnestly solicited...by December 15, 1970... Address responses to ASEE, Suite 400, One Dupont Circle, Washington, D.C. 20036

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OBJECTIVES AND PROCEDURES OF THE ASEE STUDY OF ENGINEERING TECHNOLOGY

After a series of internal discussions extending over a period in excess of a year, the American Society for Engineering Education made a proposal to the National Science Foundation in March of 1969 that NSF sponsor a two-year study of Engineering Technology Education. This proposal was based in part upon recommendations of an *Inventory Conference on Engineering Technology Education* held January 22-23, 1968 in Washington, D.C. and attended by some twenty-five individuals representing engineering and engineering technology educators, industrial employers, and governmental and other agencies. In its introduction, ASEE's proposal stated the following objectives:

> This document is a proposal to the National Science Foundation for support of a national study of engineering technology education. Such a study would inventory the current national effort in programs of two to four years duration in engineering technology education, assess the strengths and weaknesses of current educational practice in this domain, and suggest directions for future effort in this area.

As to implementation, the proposal contained this statement.

> It is proposed further that this study be implemented primarily through a series of conferences involving engineering educators, engineering technology and junior college educators, employers, personnel managers, representatives from labor, government and the armed forces, graduate engineers and technicians, representatives from the professional societies, and knowledgeable laymen.
>
> The project will be directed by an experienced educational administrator. Preliminary reports of initial findings will be circulated to institutions, organizations and agencies for purposes of early review and evaluation. This is essential in order that grass-roots participation will be assured and reflected in the final action and implementation of the results.

Based upon this proposal, ASEE was provided with funds by NSF to complete a two-year study of Engineering Technology Education beginning in August, 1969.

Preceding the distribution of the Preliminary Report the following activities have taken place.

1. A staff was assembled consisting of the part-time services of two previous presidents of ASEE and a full-time technical associate who has had previous experience both in teaching and in administration in institutions providing technician education.

2. Two meetings of an Interim Steering Committee were held for organizational purposes. The activities of this Interim Steering Committee also led to the appointment by the President of ASEE of an Advisory Committee of 24 members; the members of the Advisory Committee are listed at the end of this section.

3. This Advisory Committee has held four two-day meetings. It has received reports prepared by the staff and by subcommittees. Staff members have reported to the Committee on visits to some 50 institutions having either 2-year or 4-year programs in engineering technology. It has revised reports as received to reach a concensus and has reviewed drafts of the Preliminary Report at two successive meetings. However, since a large committee cannot be expected to write or edit an extensive report, the responsibility rests heavily with the staff, primarily the chairman.

4. This Preliminary Report has been prepared after the first year of the Study. The objective of distributing a report at the half-way stage of the study is to sample grass-roots opinions and attitudes, and to the maximum extent possible obtain feed-back based upon factual knowledge that has not already reached the staff or the Advisory Committee. *It is requested, therefore, that each interested or involved institution, technical or engineering society, industry or agency generate a study committee to review the Preliminary Report in detail, formulate its own views and transmit an analytical report backed by as much factual data as possible to ASEE Headquarters, Suite 400, One Dupont Circle, Washington, D.C. 20036.* To be of greatest value such analysis should be received by December 15, 1970, but every communication will be reviewed whenever received.

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SECTION 2

HISTORY, TRADITIONS AND TRANSITIONS

The Beginning of Technological Education

Compared to liberal higher education, the roots of which in the Unite States reach back to the founding of Harvard in 1636, technological educat has a relatively brief history in this country. While almost all of the colonial colleges were by 1750 teaching mathematics and science, frequentl including technical subjects such as surveying and navigation under the he of mathematics, it was not until 1802 with the founding of the Military Academy at West Point that appreciable attention was given to technologica education (Brubacher and Rudy, 1958, p. iii).

The world beginnings of modern technological education are only sligh more remote than those in America. The earliest date usually cited is 176 the year of the founding at Freiburg, Germany, of a technical mining schoo Some historians accept 1775, when the French Ecole des Ponts et Chausees c ed, or 1794, when the great Ecole Polytechnique was established (Read, 193 p. 351).

The Development of Engineering Schools

After its tardy introduction to the higher education enterprise in th country, technological education eventually flourished. Norwich Universit founded a Department of Civil Engineering in 1819; Union College founded a similar department in 1845; Harvard established the Lawrence Scientific Sc in 1847; Yale, in 1847, began a department which later evolved into the She Scientific School; and the Massachusetts Institute of Technology, perhaps most renowned of all the institutions of its type, was established in 186 (Brubacher and Rudy, 1958, p. 62). The Morrill Act of 1862 greatly stimul the founding of such institutions. By the beginning of this century, some engineering colleges had been established. In 1970, a total of 274 engine schools were identified (Alden, "Enrollments", 1970).

Early Development of Technical Institutes

During the same period in which engineering colleges developed, a se distinctly different kind of educational institution was emerging also. was the "mechanics institute." Schools of this type were founded mainly eastern and mid-western industrial centers, and made their first appearan during the 1820's. These early institutions may be regarded as the precu of technical institutes. They offered courses in mathematics, bookkeepin surveying, navigation, and other vocational subjects; they sought the "pr

motion of the useful arts"; they trained artisans and draftsmen. They attempted to provide training to meet the manpower needs of an expanding industrial economy for draftsmen, supervisors, designers, production workers, and other technical personnel which neither the secondary schools nor the engineering colleges were meeting directly at that time (Smith and Lipsett, 1956, pp. 18-20).

The first of the technical institutes was the Gardiner Lyceum, in Gardiner, Maine, established in 1822 (Wickenden and Spahr, 1931, p. 4). This school, however, ceased to operate after ten years. Most of the early institutes suffered a similar fate. Only one, the Ohio Mechanics Institute, established in 1828 in Cincinnati, is still in existence; it operates now under the name of the Ohio College of Applied Science. The spread of free public education is cited as a cause for the rapid waning of interest in these schools (Smith and Lipsett, 1956, p. 19).

Later Interest in Technical Institutes

Later in the century, a revival of interest in technical institutes occurred, due largely to spreading industrialization. Spring Garden College, still in existence, although renamed, was founded in 1851 in Philadelphia. Pratt Institute, Brooklyn, New York, was established in 1877 as an institution of this type, but it gradually changed into a traditional engineering school. According to Graney (1965, p. 9), there were "dozens of such institutions started during the late nineteenth and early twentieth centuries." These "flourished for a period of time and then disappeared from the scene." Graney characterized these institutions as follows:

> They geared their instruction to the maturing technology of the time, laying emphasis upon application with intensive instruction during short periods of less than four years. If they tended to prepare artisans, at least to some degree, it was because such artisans as they prepared were qualified, themselves, to bridge the gap between practice and theory.

Development of Community Junior Colleges

Community junior colleges, especially in recent years, have made important contributions to the domain of technological education.

Junior colleges first appeared as identifiable institutions during the mid-1800's (Bogue, 1956, p. 2). The stated objectives of the early institutions were to provide lower division university studies for transfer or general education purposes. After 1900 the junior college movement prospered and the number of junior colleges increased until in 1921 there were 207 such institutions, 70 public and 137 private (Thornton, 1960). Further growth has been rapid as is shown by Table 1. It was in the 1920's that the concept of occupational education as an integral part of the junior college curriculum received

substantial acceptance. The number of occupational or "terminal courses", as they were titled, grew from 100 in 1921 to 400 in 1925, 1600 in 1930, and more than 4000 in 1940 (Hill, 1942).

TABLE 1.--Number of Community Junior Colleges and Total Enrollments for Selected Years, 1900 - 1969[a]

School Year	Total Number of Colleges	Total Enrollment
1900 - 1901	8	100
1921 - 1922	207	16,031
1938 - 1939	575	196,710
1952 - 1953	594	560,731
1958 - 1959	677	905,062
1967 - 1968	993	1,954,116

[a]Sources: James B. Thornton, *The Community Junior College* (New York: John Wiley and Sons, Inc., 1960), Table 3, p. 155; and American Association of Junior Colleges, *Directory/1969* (Washington: AAJC, 1969), p.6.

Nearly 90 percent of all American community junior colleges now offer occupational education programs intended to prepare students for immediate gainful employment upon graduation. Engineering technology curricula are often included in these community college offerings. In 1968, for example, the American Association of Junior Colleges reported that approximately 300 community institutions offered organized curricula in engineering technology or a closely related field. Such technology programs generally lead to the award of associate degrees.

Community colleges also may offer occupational programs which are post-secondary and have a vocational emphasis, but which lead to the award of certificates rather than degrees.

Baccalaureate Technology Programs

Very recently, a new stream of technological education has emerged, namely, the baccalaureate-degree program in engineering technology. While two-year associate-degree technology programs have a history extending over half a century, being associated with both technical institutes and community colleges, the concept of a four-year curriculum is a contempory development. An early allusion to the idea came in 1957, when J. C. Elgin, of Princeton, wrote in *The Engineer*:

> We should expand the numbers of people trained at the technician level. This can be done through the development of the technical institute, by increasing the number of such two-year--or even four-year--technical institutions, and by

> stressing the recognition by industry as engineer-technicians and engineering aides, of those so trained.

In June 1965 Harold A. Foecke, then Specialist for Engineering Education, United States Office of Education, stated that more than sixty colleges were offering four-year technical curricula. A subsequent research study identified 73 institutions which purported to offer baccalaureate engineering technology programs or programs in "an industrial technology closely allied to the engineering field" (Defore, 1966).

A number of forces appear to have encouraged the inauguration of baccalaureate technology curricula. The two-year technology programs at technical institutes are "bulging from within" as more and more subject matter is added to the curricula. And at the same time, there appears to be an "upward push" due to complexity of industrial enterprise about which Grant Venn (1964) has written as follows:

> Now, technology has advanced many occupations on the technical, skilled, and semi-professional levels to a point where they require higher levels of specialization and related knowledge that are best learned within educational frameworks. Manifestations of this upward push are to be found, for example, in engineering, where the two-year engineering technology curricula of today compare in rigor and breadth with the four-year engineering curricula of twenty-five years ago. As engineering continues to become more complex and specialization is delayed, graduate study will become a must for the engineer, and, by the same token it is probable that within the present decade the bachelor's degree will become a must for many technical occupations.

There also appear to be parental, peer group, and societal pressures for individuals to obtain baccalaureate degrees as a matter of personal or family prestige. A related and even more important drive is to obtain an education that is known to provide upward mobility with experience.

Parallel to the development of baccalaureate engineering technology programs is another important movement. Colleges, schools and departments of industrial education and industrial arts have devised curricula which are intended to provide students with routes to industrial employment rather than to teaching. The first of such "industrial technology" programs was reported in 1923 at Bradley University. Currently, 94 are identified (Stuessy, 1970), and more are projected. The relationship of these programs to engineering technology education will be considered later.

Factors Influencing Change

A number of social forces currently appear to be influencing changes in the nature of engineering technology education. Changes in engineering education, trends to extend engineering technology programs to four years, the proliferation of community colleges offering two-year technical programs, the emergence of industrial technology programs from the area of vocational teacher education, and changes in the social-technological environment itself are factors which are serving to give new directions for the evolution of engineering technology education.

SECTION 3

ABSTRACTS OF FOUR IMPORTANT REPORTS OF TECHNOLOGY EDUCATION SINCE 1960

(A) Characterististics of Excellence in Engineering Technology Education

The present ASEE Engineering Technology Education Study covers both associate-degree and baccalaureate programs. However, since an excellent study on two-year programs was published by ASEE in 1962, entitled *Characteristics of Excellence in Engineering Technology Education*, considerable advantage will accrue from using the results of that study, commonly called the McGraw Report, as background. The following abstract of the McGraw Report seems of sufficient importance to include in this document.

It is the opinion of the Advisory Committee that the standards presented in the ASEE report on *Characteristics of Excellence in Engineering Technology Education*, which have formed the background for ECPD accreditation of engineering technology curricula, have produced a continuous desirable upgrading of engineering technology education. The following quotations summarize the 1962 report.

Purpose and Terminology

This report, seeks to develop guidelines and definitions, to suggest minimum standards for selecting faculty and students, and to explore curriculum requirements for both technical and nontechnical areas. To avoid the ambiguity of the term "technical institute curriculum" it recommends the use of "engineering technology" and "engineering technician" to represent the field of study and the practitioner respectively.[1]

Definitions

Engineering technology is that part of the engineering field which requires the application of scientific and engineering knowledge and methods combined with technical skills in support of engineering activities; it lies in the occupational area between the craftsman and the engineer at the end of the area closest to the engineer.

Engineering technology is concerned primarily with the application of established scientific and engineering knowledge and methods. Normally engineering technology is not concerned with the development of new principles and methods. Technical skills such as drafting are characteristic of engineering technology.

[1]These terms have become common usage.

Prediction of Educational Level

There has been in recent years a steady increase in the mathematics and science levels of the curricula of both the secondary school and the engineering college. The engineering technician of tomorrow *must* be educated at a higher technical level than he has been in the past. Though it is difficult to accomplish in the short span of two years, there are certain areas (e.g. mathematics, physical sciences, humanistic-social studies) in which the student must be given a broader base than has heretofore been the common practice.[1]

Faculty

Since these curricula are so closely related to engineering, it is equally obvious that a satisfactory engineering technology faculty must contain a substantial proportion of graduate engineers. It is the Committee's opinion that approximately half the faculty members *teaching the technical specialties* should be graduate engineers or the equivalent. A significant proportion of the faculty must have had relevant industrial experience which is reasonably current.

Admission Requirements

The committee believes that a satisfactory engineering technology program should be based upon the following minimum secondary school units:

(a) Three units of English

(b) Two units of mathematics, one of which is in algebra and the other in plane geometry (or the equivalent of these in integrated modern mathematics)

(c) One unit of physical science with laboratory (wherever possible, physics or chemistry)

The student should have acquired this minimum background before entering the engineering technology program itself.

Engineering Technology Curriculum

An engineering technology curriculum differs significantly from a pre-engineering curriculum, which is equivalent to the first two years of an engineering program. The technology curriculum must initiate specialized technical courses early in the program. The following table summarizes the minimum semester hour recommendations of this report along with an illustration of their possible application to a 72-hour curriculum. The 72-hour program is an example only; many variations are possible.[2]

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[1]In retrospect it seems that the 1962 report presaged the current movement into engineering technology curricula of four years duration.

[2]The report mentions more extensive curricula up to three years in length.

CURRICULUM SUMMARY IN SEMESTER CREDITS

	*Minimum		Illustration	
Basic Science Courses				
Mathematics (e.g. algebra, triganametry, calculus)	9		12	
Physical Sciences (e.g. physics, chemistry)	6	15	6	18
Non-Technical Courses				
Communications (e.g. English compasition, speech, report writing)	6		6	
Humanistic-Social Studies (e.g. economics, literature, history)	6		6	
Other (e.g. management, human relations, or additional humanistic-social studies)	3	15	3	15
Technical Courses				
Technical Skills (e.g. drafting-basic, manufacturing processes)	6		6	
Technical Specialties (e.g. semiconductors, strength of materials)	24	30	33	39
Totals		60		72

*Institutions should view with concern any curriculum which meets only the minimum shown above. Variations above the minimum are not only expected but desirable.

Mathematics and Physical Sciences

All branches of engineering technology are built upon a foundation of mathematics and physical science. Mathematics is one of the more critical determinants of both the level and the quality of an engineering technology curriculum. The most common criticism by graduates and employers is directed toward the level of mathematical content of engineering technology programs. There is no doubt that the ultimate depth to which the physical science and technical specialties portions of the curriculum can be pursued will be determined greatly by the mathematical preparation of the student.

Recommendations:

(a) Mathematics taught in the engineering technology curriculum should be college level and emphasize problem solving rather than extensive mathematical proofs.

(b) Mathematics should generally be taught in separate courses from science and technical subjects by qualified mathematics instructors familiar with the engineering technology objective.

(c) Enough Calculus should be taught to guarantee that students are professionally literate and to permit use of this mathematical tool in the technical specialties.

If the mathematical sciences underlie all the technical courses in the curriculum, similarly the physical sciences give them unity. Thus, it is to the physical sciences that the engineering technician must look for the fundamental concepts which tie together all the technical areas. Toward this end the courses should emphasize the understanding, measurement and quantitative expression of the phenomena involved. Physical science courses should be accompanied by appropriate laboratories. Careful work, precise observation and accurate measurement and recording should be emphasized.

Nontechnical Courses

An engineering technician's education should include instruction in linguistic communication, humanistic-social studies, and other appropriate nontechnical studies. Technicians have expressed the need for better preparation in English and report writing. Engineering technology curricula must educate students not only for immediate employment after graduation but also for subsequent development as citizens and responsible human beings and should whet interest in personal development in these areas after graduation.

Technical Skills

The ASEE *Report on the Evaluation of Engineering Education* (1955) indicated that future engineering curricula would probably show a decrease in the proportion of time devoted to technical skills such as drafting and manufacturing processes. The engineering technician has been expected to move upward to fill this gap. Graphic expression is as much a part of technical language as is mathematics. Every engineering technician should have a first hand knowledge of the general capabilities, limitations, and economics of the conventional manufacturing or construction techniques used in the industry in which he works.[1]

Technical Specialties

The technical specialties, or majors, cover such areas as electrical, electronic, mechanical, civil, chemical and construction technology. The technical specialties are always in transition. What today is an innovation in professional engineering tomorrow becomes the established engineering practice falling within the province of the engineering technician. Technical specialties courses should include considerable attention to problem identification and solution and should also emphasize the quantitative analytical approach. Provision should be made for a design project or course in which the student is required to integrate the knowledge obtained throughout the program.

Laboratories and Library

Theory courses in the technical specialties should be accompanied by coordinated laboratory experience which stress measuring physical phenomena and collection, analysis, interpretation and presentation of data. Students should be reasonably familiar with the types of apparatus that they may encounter in industry.

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[1]The anticipations of both the 1955 and 1962 ASEE reports with respect to the area of technical skills seem to have been fulfilled.

Use of the library is essential in all forms of higher education. The library supporting an engineering technology program should be one which will encourage the student to develop the habit of consulting the technical press and professional journals in his field. The library should also support adequately the nontechnical portion of the curriculum.

(B) Report on Recommended Guidelines for Evaluation and Accreditation of Four-Year Programs of Engineering Technology

This 1966 report of the Committee for the Development of Guidelines for Evaluation and Accreditation of Four-Year Programs in Engineering Technology Education, known as the McCallick Report, followed the ECPD decision of 1965 to include four-year or baccalaureate Engineering Technology programs in its list of accredited curricula. This committee was appointed by the Chairman of the ECPD Committee on Engineering Technology to develop criteria to guide the accreditation process for baccalaureate engineering technology curricula. The following quotations are from this 1966 report.

Recent Developments

Three recent developments are important:[1]

First--programs with a vocational heritage and flavor have been modified and extended, in some cases to two years of post-secondary education leading to associate degrees. Some important distinctions of kind and quality have been blurred by the extension of these vocationally-related programs and their identification as engineering technology programs.

Second--the emergence from an industrial arts heritage of four-year degree programs most commonly designated industrial technology. Long standing bachelor's degree programs in industrial arts or industrial education are now being paralleled by degree programs in industrial technology to prepare graduates for industrial employment.

Third--enrollments in technical institutes (two year programs) have been at a virtual standstill for the last five years while enrollments in programs leading to baccalaureate degrees have soared.

Concepts Underlying the Recommended Criteria

The Committee feels that it should maintain meaningful distinctions between engineering and technology, between the purposes of the respective programs, and between the normal roles and career patterns of the graduates.

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[1]These three developments as seen in 1966 are still continuing. They form the basis for considerable concern that distinctive criteria for four-year engineering technology programs have not as yet been put into effect in accreditation.

In this report technology concerns the achievement of some practical objectives through the application of proved "techniques", methods, and procedures.

Most engineering problems have no single or obvious best answer and hence require engineering judgment of the most appropriate balance between competing requirements. Technical problems are more likely to have unique and specific solutions. Most truly engineering problems have one or more important nontechnical constraints (legal, social, economic, aesthetic, etc.). Engineering is a profession in part because of the engineer's responsibility to society to take account of these nontechnical dimensions and thus protect and serve society's interests. The technologist or technician, as such, has no comparable professional obligation. Once the engineer has rendered a professional judgment on such relevant nontechnical dimensions of an overall engineering problem, and thereby stripped it to its technical core, if the remaining problem involves no novel technical features and requirements, the engineer may appropriately rely for the technical design upon a technologist.

We are anxious to avoid the development of any competition between engineering and technology education. They are natural supplements rather than competitors and it is our responsibility to make this eminently clear.

Recommended Criteria

A. Program Designation. The committee recommends that the program be designated by the noun *technology*, not *engineering*. The adjective "engineering" in the compound term "engineering technology" would be approved. In every respect, the institution must make it eminently clear that the program is a technology program (not an engineering program) preparing technologists and technicians (not engineers).

B. Degree Designation. The committee expresses a strong preference for "Bachelor of Technology" as the name of the degree.

C. Entrance Requirements. The committee recommends that the entrance criteria now employed by ECPD for the accreditation of engineering technology programs be continued unchanged.

D. Program Arrangement. The committee approves either the integrated single four-year curriculum or the two-plus-two plan whereby the first two years lead to the associate degree.

E. Total Credits Required. The Committee recommends that the total credits required for graduation range between 120 and 144 semester hours exclusive of ROTC and physical education. The Committee prefers the low end of the range.

F. Subject Matter Distribution. The committee recommends the following distribution:

1.	Communication, humanities and social sciences	20%
2.	Mathematical and physical sciences	20%
3.	Technical science	15%
4.	Technical specialty	25%
5.	Technical electives	10%
6.	Free electives	10%

Definition of Technical Sciences. In these courses the technologist learns the theoretical characteristics and properties of devices, systems, structure, and processes, as well as the appropriate methods of analysis--mechanics, electric circuit theory, fluid mechanics, thermodynamics, etc.

Definition of Technical Specialty. (a) Technical Skills and Techniques include graphics, surveying, construction techniques, production methods, maintenance, etc. (b) Technical Design courses include practice-oriented standard design applied to work in the field--such as construction--in which the student acquires experience in carrying our established design procedures.

Technical Electives. These support the student's career interests, and may include not only additional mathematics, natural science and technical science, but also labor relations, cost accounting, contracts and specifications, etc.

(C) ASEE/ECPD Report on Terminology For Engineering Technology

In 1967 a joint committee of ECPD and ASEE made recommendations on terminology for engineering technology that have improved communications. The report covers terminology applicable to institutions, graduates and degrees. The following refers to institutional terminology:

> It is recommended that the term "Technical Institute" be used as the generic term to designate the institution or unit awarding the associate degree in engineering technology; and that the term "College of Technology" be used as the generic term to designate the institution or unit awarding the baccalaureate degree in engineering technology.

On the subject of designation of graduates the report states the following:

> It is recommended that the term "engineering technician" be applied to the graduates of the associate programs in engineering technology and that the term "engineering technologist" be applied to the graduate of the baccalaureate program.

It was found that a considerable range of degree designations are used, including the following: Associate in Science, Associate in Applied Science, Associate in Engineering, Associate in Technology, and Associate in Engineering Technology; and also Bachelor of Science, Bachelor of Technology and Bachelor of Engineering Technology. For clear and unambiguous identification of graduates the following recommendations were made:

> It is recommended that the transcript and the diploma indicate clearly that the program is one in engineering technology.

> It is recommended that the degree designation include the term engineering technology.

It is believed that there is a continuing influence of this report which is gradually bringing greater consistency to the terminology of engineering technology education, thus clarifying both its relationship to and its separation from engineering education.

(D) Industrial Technology: An Abstract from the California State Colleges Study of 1970

Engineering technology education interfaces along one boundary with engineering education and along another boundary with industrial technology education. Therefore, it is necessary to understand the current development and status of industrial technology programs and the use within industry of IT graduates in order to establish criteria for distinguishing between ET and IT educational programs. Since the ASEE study could not be extended to cover industrial technology, dependence is placed upon published material, the most comprehensive and recent study being that of the California State Colleges entitled "Industrial Arts/Industrial Technology" published February, 1970. Part II of this publication is a comprehensive study of industrial technology education including an industrial survey that was completed by 44 percent of the 290 companies contacted. Although all firms were addressed in California a large percentage are national in scope. Also, the responses were reasonably balanced between companies with major interests in aerospace, chemicals (including wood and paper), manufacturing, electronics, food, and others (including utilities). Size was equally divided between firms employing over and under 5,000 persons. Hence the results of the survey seem applicable broadly, and they also appear to be in close agreement with less intensive national surveys and local ones made in Cleveland and elsewhere. The remainder of this section will be a series of quotations from this publication including a summary of the results of its industrial survey.

Background and Definition

Although not all institutions which offer some version of industrial technology employ this particular title, it is the most common one, and appears to be gaining even wider acceptance. The formation of the National Association of Industrial Technology in 1967, as an entity separate from the American Industrial Arts Association, is a sign that industrial technology is coming of age. The "position paper" of the California Council on Industrial Arts Teacher Education (1968) characterizes today's industrial technology program as:

> ...preparing students for such positions as those in planning, supply, product utilization and evaluation, production supervision, management, marketing research, and technical sales. These graduates are capable of analyzing problems, as well as recommending, implementing and supervising appropriate solutions. They satisfy the emerging need for technical administrators in industry.

Weber in 1961 pointed out that:

> The main difference between industrial technology and the other types of programs [i.e., industrial arts teacher education and technical institute training] is the general area of preparing students for positions in management.

...The graduate, though having knowledge of basic industrial skills, is oriented towards assisting and directing the development program, the flow of production, the distribution of the product, and other facets of general management. The technologist supervises operations involved in the development of a consumer product, or its movement to the distribution point, and even making it acceptable and popular on the open market. Some curricula offer variations in the business portion, permitting a sales emphasis, for example.

The following incorporated quotations come from the 1967 Dean Report (from the name of the chairman of a committee of the American Vocational Association which drafted it; the Report contained much material from a paper by Cunningham (1966), a member of the committee.) The high level technologist...is described as:

> ...a college graduate who is associated with managerial and scientific activities in the industrial field.... He supervises and manages people, coordinating their efforts in the utilization of materials and machines in producing and distributing industrial products.

As the chief objective, the Report acknowledges that the [IT] curricula:

> ...are oriented more toward training for supervisory and middle management positions. It is presumed that graduates...will be employed in positions requiring leadership qualities and a broad knowledge of those supervisory and administrative functions which result in the efficient operation of an industrial organization.

With regard to the appropriate curriculum to prepare the technologist, the Report states:

> The training includes a basic knowledge of some engineering and management principles, a broad knowledge of industrial processes and the operation of machines and equipment, in addition to applied technical and practice skills. The chief asset of the training is that the graduate of such a program is provided with a broad background...which makes him flexible and adaptable to almost any kind of industrial organization with a reasonable amount of in-service or job orientation training.

Industrial and Engineering Views

Defore's study (1966), done from an engineer's point of view, purports to deal with baccalaureate engineering technology programs, but it makes the assumption that many industrial technology programs are closely enough "related to the engineering field" to qualify for inclusion among the 73 institutions in 33 states offering 189 curricula covered. ...In comparing four-year engineering technology with two-year associate degree programs, Defore finds that the mean numbers of semester hour credits required in engineering science, mathematics, and communications are approximately the same in both baccalaureate and associate degree curricula, although the number of credits represent slightly smaller percentages of the total requirements in the baccalaureate curricula than in the associate programs. In the baccalaureate curricula, however, an appreciably larger proportion of the total requirement lies in humanities and social studies. Baccalaureate curricula have a mean requirement of 34 semester hours credit in technical specialty subjects, or 26% of the total; the associate, 22 for 32%. Although the total requirement for the baccalaureate degree is nearly twice that for the associate degree, the mean requirement in the technical specialty for the baccalaureate is only 55% more than for the associate.

A study by Jacobsen (1966), done under the auspices of HEW, is an ambitious attempt to survey and identify technological manpower needs of industry and to relate these needs to curriculum development in higher education. The conclusions are based on questionnaire returns from approximately 1,100 companies across the country.... Among the more significant findings of the survey are the following:

1. Nearly 20% of engineers in a typical company serve the functions of a technician. Industry shows little respect for the engineering title.

2. Industry indicates that the most satisfactory preparation for the technician is the four-year college with a technical training program. It is estimated that at least 20% of the additional technicians needed should possess the bachelor's degree or more.

3. Industry prefers general technical training to other types. Significantly, those companies which prefer general technical training most frequently rank four-year colleges with technical trainee programs as the most satisfactory technician programs.

Jacobsen comments: "Clearly there are not enough technicians available to meet the demand of industry, and the industrial demand is growing."

History of the Four-Year Technology Program

Historically, four-year technology programs developed from two principal sources, namely, the technical (engineering) institutes and the industrial arts departments of colleges and universities. The technical institute was the original two-year post-high-school institution engaged in preparing middle-level technical personnel for industry, that is, support personnel for the engineering function. In employing the concept of the "engineering team", with the skilled craftsman at the lower end of the spectrum and the professional engineer at the top, the institute was spelling out its role in training the middle member of the team, the technician who acted more or less as an assistant to the professional engineer and as a liaison person between him and the craftsman.

The engineering profession, accepting the "team" approach, proceeded through the professional organizations to fix duration and content of the educational preparation needed by the technician and to accredit the better programs. It is significant that the engineering profession relied almost exclusively on these specialized institutes rather than on regular colleges and universities to train its support personnel, and that prior to the 35th Annual Report of the ECPD (1967) the profession officially conceived the two-year program as sufficient attainment for the engineering technician.

Four-year programs, which are essentially elongations of the training time of technicians, were for a long time ignored by ECPD. Indeed, institute faculties felt so estranged that they often attended conferences sponsored by industrial arts organizations, where mutual problems affecting four-year technology programs were discussed. However, these institutes account for a very small percentage of the institutions offering some form of four-year technology programs. In the majority of institutions, four-year technology programs grew out of industrial arts departments, beginning as technical tracks distinct from teacher education. This development occured partly in response to pressures from local industrialists.... Industry's need became even more acute as societal, parental, and peer pressures placed a premium on the baccalaureate degree, thus discouraging students from enrolling in two-year technician programs....

[Via] siphoning off of some prospective industrial arts teachers into industry, and thus perceiving industry's need, many industrial arts educators were receptive to industry's overtures. Moreover, such development appeared to be consistent with the discipline's emerging objective of teaching about industry and technology and the pressures being exerted on it from other departments to offer certain technologically-oriented service courses. Speaking for the vanguard technical institute and industrial arts educators, Wheaton (1964), observed "that the well-educated top technician group should not consist of those who failed to complete engineering or science college curricula," but there should be a separate four-year program designed expressly to meet industry's needs.

Foecke (1965), formerly engineering specialist with U.S.O.E., provided a well-conceived rationale and urged ECPD to recognize and accept four-year engineering technology as a legitimate addition to the engineering education spectrum and the technologist as a full-fledged member of the engineering team. As a result, a committee was formed to study the issue and make recommendations. On the basis of the McCallick Report (1966), which recognized the "crisis" aspect and was generally favorably disposed toward four-year engineering technology, and in spite of some serious problems in reconciling it with professional engineering, the ECPD adopted the recommended criteria for accrediting the stronger programs.

Evolution of Industrial Technology

In the evolution of the typical industrial technology program, a pattern is discernible. Starting as a technical track or option within the established industrial arts curriculum, industrial technology was naturally heavily weighted with the only resource that was abundant: industrial arts courses.... However, only programs in very small colleges tend to remain long in this transitional stage. As industrialists are consulted about their needs and drawn into active curriculum development, and as faculty who possess recent industrial experience and enthusiastic commitment to the program are hired, separate courses with the IT prefix are introduced and their content tends to approximate the objectives more closely. Particularly if the program is located in a large, comprehensive institution, producing the technologist with managerial capability becomes the chief objective; the means consists of "mixing" appropriate courses from several professional areas--preeminently industrial arts and business, but also engineering, mathematics, science, art, psychology, English, speech, journalism, and humanistic and social studies....

Courses from other professional disciplines complement the more distinctly technological portion of the curriculum. This portion generally consists of (1) a technical "core" comprising knowledge that is basic to efficient performance in all functions of technology, and (2) a technical specialty. Gradually, the technical specialty, which originally consisted of one or more of the traditional industrial arts fields, yields to a focus on a "cluster" of industries, such as manufacturing, construction, and electricity/electronics, or sometimes on a job category, such as sales. The general program, characterized by great flexibility and adaptability, has passed into its most sophisticated form when the content is well-suited to the objective of preparing the technical administratcr. By this time it is usually a separate curriculum leading to its own degree. At most the industrial arts portion of the curriculum consists of providing the basic skills and knowledge and contributing to the technological specialty as appropriate. ...The breadth of preparation which is characteristic of industrial technology stems from awareness on the part of educators that they would be doing a disservice to graduates if, since technology changes at such a breathtaking pace, they trained them too specifically for skills that will be obsolete quickly.

Industry's View on Curriculum

Industry itself supports the broader type of program. By a two-to-one margin respondents to the Survey of Industry prefer technologists to have an educational background which is broad and flexible rather than overly specialized. The margin turns out to be even greater when the responses of the one-third indicating a need for technologists with more specialized training are analyzed. Three out of four of those firms which distinguish between engineering and industrial technologists and employ both types prefer that the industrial technologists be more broadly trained....

Most courses carrying the IT prefix are substantive and, in their totality, apparently well-geared to the needs of industry. The Survey of Industry verifies this. In providing knowledge that is essential to efficient performance in all functions of the technology division, some courses may be said to make up a sort of "core"; but the composition of the core varies too much from institution to institution to identify it as a standard feature of industrial technology.

One purpose of the Survey of Industry was to discover what industrialists consider desirable content for an industrial technology program. The following pattern emerges from the respondents' distribution of unit-time according to the six general subject areas which comprise industrial technology:

Subject Area	Percentage of Total Program	Indicated Equivalents in Semester Units
General Education	20%	25
Communication Skills	12%	15
Mathematics	12%	15
Science	13%	16
Technical Subjects	26%	32
Business Administration	17%	21
Totals	100%	124

Characteristics of a Quality Program [Abbreviated]

1. It leads to a Bachelor of Science degree in four years without crowding.

2. It profits from continual study including an advisory council of business and industry.

3. It prepares primarily for supervisory-managerial positions in industry.

4. It is broad rather than specialized...it is truly interdisciplinary.

5. It requires mathematics through analytical geometry and calculus [introductory], one year of physics, a semester of English composition, a speech course, a course in technical writing, 18 semester hours of business, a course in computer science, a course in industrial psychology, and ability to read blueprints in addition to courses in the technical specialty and related studies.

6. The faculty, in addition to having requisite academic background and teaching competence, possesses previous work experience in industry and continues to keep abreast of current developments through close contact with, and summer employment in, industry.

The Need for Technologists

Industry's present and accelerating future need for high-level technical personnel is well documented. The national surveys of industry conducted by Jacobsen and Defore...confirm it. Jacobsen, for example, estimates that for every two technicians employed in 1967, three will be needed by 1972 and at least one-fifth of them will be required to have a baccalaureate or higher degree. This represents at least a doubling of the need for technicians with the bachelor's degree from 1967 to 1972.

...For predictions of need on the national level, two documents, Occupational Employment Patterns for 1960 and 1975 (BLS, 1968) and Tomorrow's Manpower Needs: National Manpower Projections and a Guide to Their Use as a Tool in Developing State and Area Projections (BLS, 1969) are valuable resources.... The fastest growing occupational grouping, "Professional and Technical" workers are expected to increase their share of the total employment picture in 1975 (91.4 million) by 14.6%, considerably up from 11.3% in 1965. Requirements are thus projected to reach 13 million in 1975, up 45% from 9 million in 1965 and 73% in 1960....

In any optimum solution to the manpower shortage, graduates at the two-year level should be more numerous than the four-year technologists, and the latter more numerous than the professional engineers. ...Even if the increase in enrollments were to continue at the same rate, i.e., nearly doubling again by 1975, the supply [for California] would not begin to approximate the demand. Existing programs simply could not accommodate this increase; additional ones will be needed.

Considerations of Terminology

While "industrial technology" may appear to be a rather generic and imprecise title for the type of program delineated in this report, there is at present no viable alternative.... "Industrial Technology" is the curricular and degree title generally used across the country and is coming more and more, through persistent usage, to have a meaningful identity for industry. It is consistent with the National Association of Industrial Technology, an organization created expressly "to foster the improvement of baccalaureate degree-level curricula of industrial technology within institutions of higher education," and perhaps to serve eventually as an accrediting agency as it gains recognition.

The objective of preparing the high-level technician cannot be considered necessarily incompatible with preparing the technical manager type. The fact is that the entry-level job for the technologist may be indistinguishable from that of the technician. The difference is that the technologist has been prepared to move upward as rapidly as conditions and his own abilities and ambitions allow into supervisory and managerial positions. Industry does, at least initially, not differentiate levels and duties as carefully as educators might like. As is true of most areas of human endeavor, the technologist has to serve some sort of apprenticeship. The dividend of four-year preparation over two-year lies not in making the draftsman, for example, a defter draftsman, but preparing him for upward mobility on the job.

Administration and Relation to Industrial Arts

As is the case with industrial arts, the administrative location of industrial technology programs varies from campus to campus.... Experts disagree over the question of whether joint or separate administration, classes, and instructors are better. In the June 1964 issue of *Industrial Arts/Vocational Education*, Dean and Kleintjes of Long Beach State College comment:

> There are two schools of thought regarding facilities and faculty for the technology program. First, there are

> those who believe the curriculum can and should be housed in the industrial arts laboratories and taught by the industrial arts faculty. The second group feels that separate facilities should be provided and the faculty should be entirely separate from those teaching industrial arts....

The tendency across the country, at least in the larger colleges, is for industrial technology, although it originated in and was nurtured by industrial arts, to break away and become independent at maturity.... Whether or not it is administered separately, industrial technology requires two or three specialized laboratories, one of them designed to give the student an overview of manufacturing processes and to demonstrate the elements of total production. Moreover, the industrial technology instructor must have extensive industrial experience and must maintain close and continual contacts with the evolving technology in industry.... Industrial arts students can profit from working in industrial technology laboratories, which will, of necessity, contain the latest equipment. Integration has the advantage of keeping the cost of operating an industrial technology curriculum to a minimum.

Distinction of programs by their primary function--industrial arts preparing teachers and industrial technology preparing industrial workers--must be preserved. However, a broadened conception of industrial arts is called for, as preparation for teachers not only for industrial arts classes, but for occupational classes and in-plant training programs of industry as well, in conjunction with industrial technology.

The Master's Degree

The rationale for the master's degree is both to give students who possess the bachelor's degree an opportunity to pursue advanced work and to prepare teachers for the related technical programs offered by the Community Colleges and some other colleges and universities.

A master's degree in industrial technology is not recommended at the present time. The Survey does not support the need for it. If the technologist pursues graduate work, industrialists would prefer it to be in business, leading to the Master of Business Administration. It is doubtful, too, if the baccalaureate program, being of recent origin, is seasoned or solidified enough to support a capstone degree or even whether a substantive body of advanced technical subject-matter exists to constitute a full master's program in industrial technology. Energy should be directed at strengthening the undergraduate program.

Relationship to Industry--Co-op Programs

[In California] leaders from business and industry are serving on advisory boards and councils to industrial technology programs. Such liaison has the advantage of insuring that the curricula are, and continue to be, responsive to the ever-changing needs of industry and that there is a ready-made market for graduates; but it has also had one serious disadvantage: localization has militated against evolving a national philosophy and objectives.... Still another contribution industry has made is allowing its high-caliber personnel to teach courses at nearby...colleges and universities....

Nationally, there is a resurgence of interest in work-study programs. A recent issue of *Time* disclosed that "Already 136 colleges and universities have instituted work-studies programs that provide undergraduates with a taste of a career ahead of time." Shoben ascribes their popularity in part to "dullness and lack of cogency in study in relation to the authenticity of the work experience." Under terms of an omnibus bill, extending and changing the Higher Education Facilities Act, the Higher Education Act of 1965, and the National Defense Education Act until mid-1970, several million dollars are provided for a new program of grants to colleges "to develop,

carry out, or expand cooperative education programs that alternate periods of study with full-time employment."

Finally, there needs to be closer coordination between college programs and the educational training centers operated by industry, many of which are very extensive and impressive. While in the beginning in-house training developed more as a protective device, to meet some conspicuous "ability gaps" in the educational process or to counteract education's indifference to or inability to handle special personnel needs, it has evolved into a means of *supplementing* the employee's formal educational preparation in ways the colleges cannot....

Relationship to Community Colleges

Pertinent, also, is the admonition of the McCallick Report:

> In any society such as ours where technological changes are taking place at an unprecedented rate, the very idea of "terminal" education is not only unrealistic but unthinkable.

...Mutually beneficial arrangements have been effected, whereby the Community Colleges offer pre-baccalaureate programs expressly designed to permit the student to transfer into an industrial technology program at a particular State College without loss of time or credit. ...Industrial technology is in many ways the "natural" advanced program for Community College technical graduates to enter. By design, the upper division part of the broadly conceived program concentrates on "rounding out" the student, and thus could yield readily to the two-plus-two approach. Picking up the student whose lower division training has been relatively specialized, preparing him for middle-level technical jobs in industry, industrial technology at the upper division can provide him with the means to qualify for higher-level positions through courses in management, communications, psychology, and humanistic/social studies, among others, and through advanced and integrative technology courses which give an overview of technology and the industrial enterprise....

...The contents of the vocational programs, dubiously collegiate-level in many instances, need to be upgraded. Many technical programs are too narrowly focused and excessively skill-oriented rather than concept oriented. A majority require no college mathematics at all, and practically no science, or at least not to any depth. Since there are few electives, the student has no opportunity to secure breadth either in general education areas or in general technology. Though students are, of course, encouraged to combine the occupational curricula with the requirements for the associate degree, there is not enough insistence on it and woeful lack of counselors with understanding to identify the better students and to channel them into transfer tracks.

Relationship to Engineering

In all the literature on industrial technology and the descriptions of programs, reference to producing semi-professional engineers is studiously avoided.... Of course, many graduates will actually be hired for positions that are engineering-related and will be given titles in which the term "engineer" figures prominently. Industrial technology educators can hardly be faulted for industry's tendency to ignore some academic subtleties and to use the term "engineer" loosely, especially as a means of upgrading in position.

[In definitions of engineering technology such as that of ECPD,] ...the key phrase is *in support of the engineering effort of industry*. The engineering technologist is sometimes said to be like the pre-1955 professional engineer who was more concerned with the techniques of

engineering art. With regard to the nature of the preparation required, the 1969-70 Cal Poly catalog states:

> The engineering technician is somewhat more specialized than the engineer, focusing on a narrower range of subject matter and skills. In general, he seeks less depth in basic and engineering sciences but develops more specific capability and education in technical skills and in the more essential aspects of design and production.

On the other hand, the industrial technology faculty at Cal Poly, San Luis Obispo describes its program as:

> ... that part of higher education which prepares students for professional-level (baccalaureate degree) technical occupations in industry, excluding professional engineering. This field, forming the mid-ground between engineering and business administration, emphasizes the applied aspects of industrial processes and personnel leadership. It is based upon a foundation of understanding and working knowledge of industrial materials, tools, processes, procedures, and human relations. Industrial technology includes the industrial areas of electricity, electronics, drafting, graphic arts, metal-working, wood-working, plastics and power technology. This specialty requires high levels of ability in: (1) working effectively with people, (2) mechanical aptitude, (3) communication-motivation skills, and (4) planning.

The key phrases here are *occupying the mid-ground between engineering and business administration* and *emphasizing the applied aspects of industrial processes and personnel leadership.*

The McCallick Report adds another dimension

> It is for the educational preparation of the engineering technician--the technician who must discharge the duties of yesterday's applications and design oriented engineer and who must be prepared for *eventual managerial positions* as well as positions of great technical responsibility--that the four-year programs in engineering technology have been developed.

In a way this is only stating the obvious, for no matter where the college graduate goes today, he will eventually be seeking a management position. The only viable advancement opportunity for the technologist is some kind of managerial position. However, in predicating this as an objective for engineering technology, and in actually including a block of business courses in the curriculum to meet it, the engineering profession is entering territory preempted by industrial technology and thus blurring the most visible line of distinction.

Possible Solutions--Relationship of ET and IT

As early as 1962, Vivian, writing from an engineer's viewpoint, noted that "industrial technology programs in the State Colleges are now a 'gray area' between Engineering and Industrial Arts and need to be controlled." He recommends that "Future programs should be interdisciplinary between these divisions and the Business Division and administered by the faculty with the highest level of technical knowledge of industry, the Engineering Division."... Vivian's recommendation had merit, but he misjudged both the attitude of the engineering faculty toward technology and the readiness of the various schools and departments to cooperate to the extent a joint program would require.

The McCallick Report, in spite and because of nagging doubts, recommends acceptance and accreditation of these [ET] programs by the following reasoning:

> ...unless criteria for accreditation of those programs are promptly adopted, considerable chaos could result. Engineering technology education, as ECPD has known it, is in jeopardy. It is being squeezed from below by two-year associate degree programs growing out of a vocational education background and is being outflanked at the four-year level by degree programs in technology evolving from an industrial arts heritage. Failure to act will neither reverse these threatening trends nor, therefore, the growth in numbers of four-year technology programs.

[It is relevant that], consistent with the recommendations of the Grinter Report (ASEE, 1955) and the subsequent accrediting criteria established by ECPD, engineering education today is theoretically oriented; the major emphasis is on the functions of design, development, and research, especially on the first, rather than on production and manufacture. Institutions have exerted tremendous effort over the last dozen years in securing ECPD accreditation, and most engineering faculties do not seem persuaded at this time that the hard-won gains should be jeopardized through diversification into engineering technology programs. The McCallick Report asserts that:

> ...a number [of industrial technology programs] are sufficiently similar that they could readily be converted to engineering technology programs with only minor changes in curricula and objectives.

Yet in making this assumption, the committee implies that the engineering profession can absorb industrial technology, and is willing to do so. The direction engineering education will take in the future is simply not clear enough for such a commitment to be made. The Engineering Goals Report (ASEE, 1968) recommends, in view of the manifest trend for engineers to pursue advanced work, that the master's degree should become the entry level into the profession. If this recommendation should indeed become the accepted guideline for the engineering profession, then the place of the emerging four-year technologist in the engineering continuum might become clearer.

...Finally it is the view of some industrialists, as confirmed by the Survey, that the goals and patterns of industrial technology are better suited to their needs than those of engineering, at least as presently constituted. As an immediate or short-term solution, then, wholesale movement of industrial technology into engineering appears neither feasible nor desirable.

<u>Recommendations [Those applicable specifically and solely to the California System or one of its member colleges are omitted.]</u>

1. "Industrial Technology" is the appropriate designation for the industrially oriented program growing out of an industrial arts heritage, and the Bachelor of Science the appropriate type of degree awarded.

2. Industrial technology shall be developed only in colleges which are already operating a strong industrial arts curriculum.

3. Colleges with strong professional engineering programs but without industrial technology may...consider developing an accredited engineering technology program if all conditions, especially a fully supportive engineering faculty, are conducive to doing so.

4. Steps shall be taken to increase cooperation among the engineering, business, and industrial arts-industrial technology areas.... In line with the principle that any program shall draw upon appropriate offerings of related disciplines in preference to duplicating them, all colleges with industrial technology programs are requested to review areas of possible proliferation of offerings and to consider incorporating appropriate *engineering* courses in the curriculum.

CSC Industrial Survey

Survey of Industry's Responses to Questionnaire. Soon after the industrial arts-industrial technology study began, it became clear that a survey of industry was needed. Whereas a good deal of information about industrial technology programs could be gleaned from existing literature, the same could not be said of industry's viewpoint toward the general concept of an industrial technology curriculum. Individual colleges had made surveys of those firms which employed their technology graduates, but these were generally regional and designed to elicit information related to their particular programs. No comprehensive survey of California's industry's need for and use of technologists has ever been undertaken. The present survey was restricted to firms indigenous to California or national firms with major branches in California....

In order to maximize mutual understanding, the first page of the questionnaire itself contained a brief descriptive statement about industrial technology and a working definition of an "industrial technologist."

...No universally accepted definition of the industrial technologist exists, but to assure that our understandings will be similar and the responses to the questionnaire thus more meaningful, the following descriptive definition will be used:

> The industrial technologist is a college graduate who is associated with the managerial and scientific activities in the industrial field. He has a solid background in mathematics, physical science, human relations, and extensive educational experience in technical theory and manipulative skills in such fields of specialization as electricity, electronics, drafting, graphic arts, metal working, woodworking, plastics and power technology. He works in the mid-ground between engineering and business administration, focusing on the applied aspects of industrial processes and personnel leadership. He supervises and manages people, coordinating their efforts in the utilization of materials and machines in producing and distributing industrial products.

Because the relationship of industrial technology programs to those called engineering technology and administered by Engineering Departments is often uncertain, you will be asked to indicate some preferences aimed at clarifying the relationship between the two.

...Detailed analysis of the responses, including many correlations and refinements, revealed both a definite pattern to the responses and

a remarkable degree of internal consistency. Patently, industry has a need for technologists with baccalaureate degrees, and this need will accelerate in the future. For curriculum planning and development, the most important finding is that industry is looking primarily for production-oriented persons who will eventually move into managerial and supervisory positions, and consequently technologists possessing a broad technical background combined with business and managerial techniques and communication skills are preferred.

...The conclusions, given in order of questionnaire items, are as follows:

1. Positions in production management and quality control are the most likely job placements for industrial technology graduates. Other job openings are commonly found in purchasing, sales, and field service.

2. According to the title description, a large number of positions held by technologists are managerial. The terms "engineer" or "engineering" appear in many job titles, even though the holder may not be engaged in true engineering or engineering-support tasks.

3. Within the general subject areas identified, respondents evaluated individual courses as follows:

   a. Mathematics--The majority of respondents consider Arithmetic, Algebra, and Trigonometry necessary courses.

   b. Technical--Courses in Blueprint Reading, Time and Motion Study, and Quality Assurance or Control are considered necessary by a high portion of respondents. Few respondents rated such specialized courses as Fluid Flow, Plastics Technology, Power Technology, Graphic Arts, Photography, or Woodworking as necessary.

   c. Business--Respondents rated a relatively large block of business courses as necessary. These include Accounting Principles, Human Relations, Introductory Economics, Management Principles, and Production Supervision.

   Generally, the responses to specific course selections reinforce the preference for technologists having a breadth of technical background combined with strong business and human relations knowledge.

4. The pattern of curriculum emerging from the respondents' suggested time distribution has been given under "Industry's Views on Curriculum." [See page 19].

5. Certain types of companies, notably electronics companies, appear to prefer students to have more technical training. However, the majority of aerospace, chemical, manufacturing, and food companies do not expect high concentrations in the technical area but rather prefer students to have more general education and business courses.

6. Respondents by a two-to-one margin prefer technologists to have an educational background which is broad and flexible rather than overly specialized.

7. About one-third of the respondents indicate a need for technologists with more specialized training--persons who can move readily into jobs which require specific technical knowledge and expertise in a single area.

8. Large companies tend to use industrial technologists and engineering technologists interchangeably; small and medium-sized companies tend to distinguish between graduates of four-year industrial technology and engineering technology curricula according to the duties performed.

<u>Analysis of Companies' Responses.</u> Number of companies receiving questionnaire, 290; number of companies responding, 154; number completing questionnaire, 129, or 44 percent.

Type of Product	Response
Space, Aero	41%
Chemical, Wood	34%
Manufacturing	46%
Electronics	76%
Food	67%

Number of Employees	Response
Under 1000	37%
1000 - 4999	44%
5000 and over*	71%

[*Large companies hire the majority of IT graduates]

<u>Positions Most Likely to be Filled by Industrial Technology Graduates.</u>

		Responses
(1)	Production Management	104
(2)	Purchasing	43
(3)	Quality Control	81
(4)	Sales	42
(5)	Logistics	12
(6)	Field Service	40
(7)	Job Development and Training	16
(8)	Market Research	10
(9)	Other	42

Educational Subjects Considered Necessary or Desirable by 70% to 99% of Respondents.[1]

Mathematics	Response[2]
*Arithmetic (College Math)	99%
*Algebra	98%
*Trigonometry	88%
Descriptive Geometry	79%
*Statistics	91%
Computer Programming	76%

Technical Studies	Response[2]
*Introductory Drafting	94%
*Blueprint Reading	94%
*Basic Mfg. Processes	96%
Machine Tool Skills	81%
Tool Design	76%
*Mechanical Systems	96%
Design Mech. Systems	84%
Design Elec. Systems	79%
Strength of Materials	84%
Electrical Power	75%
Product Evaluation	80%
*Time & Motion Study	89%
*Engineering Economy	90%
*Assurance or Control	90%
Advanced Control	80%
Industrial Design	72%

Science & Applied Science	Response[2]
*Physics	88%
Statics	72%
Dynamics	70%

Communications	Response[2]
*Public Speaking	94%
*Technical Writing	96%
Audio Visual	73%
*Psychology	92%

Business Administration	Response[2]
*Accounting Principles	98%
Marketing Principles	78%
*Human Relations	99%
*Introductory Economics	94%
Financial Management	81%
*Management Principles	98%
*Industrial Relations	95%
Customer Relations	80%
Introductory Oper. Research	76%
*Production Supervision	91%
Industrial Purchasing	87%

[1]It should be noted that the questionnaire did not list "general education" or "liberal education" so their relative importance in "job performance" was not evaluated. However, in response to a question on percentage of curricular time to be assigned to six major categories the response for "general education" ranged from 5 percent to 50 percent. More importantly, both the mean and the median of the 129 replies was that 20 percent of the curriculum should be devoted to general education. The California State Colleges require that fully one-third of the program consist of general education, but some allowance is made for communication skills, mathematics and science as parts of general education.

[2]Percentages were computed by the ASEE Staff. Percentages for starred subjects range from 88% to 99%, and the starred subjects receiving particular industrial emphasis subdivide as follows: basic subjects, 8; technical subjects, 7; business administration, 6.

Recruitment and Hiring as Related to Curriculum.[1] The following indications of preference by companies[2] relate to educational background for new employees.

		Responses[3]
a.	Prefer four-year industrial technology graduates	41%
b.	Prefer four-year engineering technology graduates	45%
c.	Prefer four-year industrial arts graduates	4%
d.	Have no preference as to type of technology graduates	7%
e.	See no need for technologists to receive more than two-year preparation	3%

[1]In addition, a majority of respondents felt able to distinguish between four-year IT and ET graduates according to the duties performed, and therefore a majority recommended separate IT and ET curricula. By a 3 to 1 margin, employers showed preference for graduates having work-study or internship experience despite their intent also to provide appropriate in-service training.

[2]Large companies showed strong preference for broad rather than specialized training, other companies the reverse. Evidently, large companies can place and shift personnel to greater advantage, and also their internal training programs are more sophisticated than in smaller companies. However, one respondent warned, "We tend to philosophize one way and hire another." A second admonished, "Interpersonal relationships are very important, but there is no substitute for technical competence." Nevertheless, a two-to-one overall preference for broad rather than specialized technologists was expressed.

[3]Percentages were computed by the ASEE Staff.

SECTION 4

RECENT TRENDS IN ENGINEERING EDUCATION AND ENGINEERING TECHNOLOGY EDUCATION

Changes in Engineering Education

The education of the engineering technician and the engineering technologist bears an inadequately defined but important relationship to engineering education. Engineering education programs appear to be again undergoing a rapid evolution. After a period in which undergraduate engineering curricula were being extended to a point where only exceptional students finished in four years, and five-year undergraduate curricula were being tried in a few institutions, a reversed trend has developed. Baccalaureate engineering curricula that can realistically be completed in four years, of comparable length to curricula in liberal arts or science, now exist in significant numbers, a trend which seems likely to continue. This trend is not due to a belief that engineering education can be completed in a normal four-year curriculum. Instead, it seems related to a growing belief that an engineer who carries professional responsibility should have a more extensive educational background than is commonly credited in professional circles to the baccalaureate degree.

Advanced Degrees

Whether the advanced professional education of the engineer is conducted as study for the traditional master's degree or for an advanced professional degree, the result seems likely to be an extension beyond four years that will effectively differentiate between the education of the professional engineer and the engineering technologist. Such a change may be expected to develop gradually; in fact, it has been in process for some time since approximately forty percent of new engineering employees now have advanced degrees.

Trends in Technician Education

The growth of technician education at the associate-degree level is a result of the establishment of large numbers of junior or community colleges. Enrollments in long established technical institutes have not been growing significantly. The technical programs of the junior colleges are extremely variable both in their objectives and their quality. It is fair to generalize that many represent an outgrowth from earlier concepts of vocational training. Some will continue within this type of environment while others, because of educational and experience backgrounds of faculty and other factors, have already changed in character. Two natural steps of evolution are identifiable: first, the introduction of some math-science requirement leading into specialized courses related to industrial processes; and second, strengthening of the

math-science requirement for use in technical courses taught at least in part by engineers. At this stage the curriculum may meet the requirements of ECPD for accreditation as an associate degree program in engineering technology. Junior colleges have not requested accreditation in significant numbers as yet (in 1969 the ECPD Annual Report lists twelve community colle ith one or more accredited associate degree curricula in engineering tec...logy).

Roots of Baccalaureate Technology Education

Baccalaureate technology curricula have roots in several areas of education. First, there have long been baccalaureate curricula in mechanized agriculture, building construction, printing, glass manufacture, furniture production and other industrially related areas. In some areas, such as textiles and petroleum, engineering accreditation for the program was sought; in others, it was not, probably because the arts were more important than the sciences in those fields. Another source of technology curricula has been the industrial arts programs of certain colleges of education where an evolution has taken place and "industrial technology" curricula have emerged. Because mathematics and science were not traditionally emphasized in vocational teacher preparation in colleges of education, the technological curricula stemming from this source have been initiated with about equal emphasis upon math-science-technical requirements and non-technical studies. It seems evident that the less encompassing math-science-technical content of curricula that have developed out of industrial arts education, commonly termed industrial technology, along with their emphasis upon management, account for rather rapid increases in their enrollments. A third source has been vertical extension to the baccalaureate level of the curricula of technical institutes which usually include a relatively large math-science-technical content.

Contemporary Developments in Technology Education

The most important recent trend in technological education is the interest of many universities in providing baccalaureate curricula in engineering technology. In some cases, the technology curricula are offered within colleges of engineering while in others these programs are provided through colleges of technology or other administrative units. Under either of these administrative plans, the faculty of the technology unit is likely to be composed heavily of teachers with considerable industrial or other experience relevant to the curricular specialty. A major fraction of those who teach technical courses may be engineers. A factor that has disturbed engineering faculties is the rapid growth in student enrollment which has followed the inauguration of nearly all of the new baccalaureate technology programs while engineering enrollments have remained static. This growth may be attributed to the fact that only a small fraction of high school students show a strong interest in mathematics and

science. Yet all are exposed to the marvels of an increasingly technological world. Thus an educational channel which provides professional or semi-professional status through technological employment without the rigorous math-science requirement of engineering curricula appeals to many high school graduates.

An important contemporary educational experiment is noted in what are called "two-plus-two" baccalaureate technology programs, those designed to attract enrollment from students who have previously achieved an associate degree. The associate degree vocational-technical programs of many junior colleges are being upgraded and are attractive to some students, but they still suffer in enrollment from their historical connection and, in some states, current association with "terminal" education. However, a growing number of universities and colleges are accepting at least the upper half of the graduates from technical associate degree programs into baccalaureate curricula in technology. Usually some academic time is lost by transfer, but if these transfers prove reasonably successful, the result on enrollments in technical junior college programs may be dramatic. The increased enrollments would then produce an enhanced flow of associate degree technicians into industry as well as a consistent flow of transfer students at the junior level into baccalaureate technology programs.

Employment of Technologists

As yet the number of baccalaureates from technology curricula is small compared to the number of engineering graduates, but the growth trend is clearly upward. Their absorption into industry should not provide any problem at least for the next decade.

Data from the Bureau of Labor Statistics indicate that currently about one million technicians are employed (BLS, 1970). Of these, about one half have no formal education beyond high school. The remainder have one or two years of post-high-school education, but only half of these seem to have received an education of two years closely related to their employment as technicians. It is likely that future utilization patterns for technical manpower will call for enhanced preparation of the individuals entering technical employment; employment priorities may justify that at least 50 percent of the new entrants to technician jobs will need education to the associate-degree level and that another 25 percent will need advanced technological education, that is, baccalaureate degrees. If four-year engineering and industrial technology education should grow in volume to equal the production of engineers, and allowing for usual losses, it would require nearly a ten-year output from such baccalaureate technological curricula to replace with such graduates one-fourth of the one million technicians now employed by industry and government. By

that time the needs of industry would doubtless have grown commensurately.

Industrialists explain that they employ for technical jobs the best qualified persons available and provide as much training as is essential to achieve the necessary productivity. Baccalaureate technologists are needed, but in their absence the best qualified technicians will be upgraded to achieve an acceptable result. The extent of the need for baccalaureate technologists will be largely invisible until the product becomes available in significant numbers for employment. The increased cost of using minimally qualified employees is equally indeterminate.

Societal Aspects of Technological Education

Since the baccalaureate engineering technologist will doubtless in due time be recognized as a member of a profession, he must develop the societal responsibility expected of every professional. Immediately he may function under the codes of ethics of engineering societies but eventually he will undoubtedly develop a code of ethics more directly applicable to his particular activities and responsibilities.

The engineering technologist will soon be involved in making his particular type of contribution to the solution of many current problems of modern society. There are contributions that can readily be made to solving many widely discussed problems without new research. We know much that we apply inadequately to urban overcrowding, crime reduction, air pollution, transportation, public health, natural resources, water conservation, lake and river contamination, wild life preservation, noise abatement, etc. The opportunity for technologists to work in such fields seems likely to increase.

In their present early stage of development, curricula in engineering technology often contain less mathematics, science and technical subjects than engineering curricula of four years duration. Engineering technology under liberal direction may therefore offer to some students a fairly extensive opportunity to expand the usual social-humanistic courses into a study of considerable depth in some non-science area such as economics, sociology, political science, law or humanities. Such an interdisciplinary interest may be expected to lead students toward an opportunity to contribute to future technological solutions of societal problems. Other possibilities of non-scientific emphasis are, of course, management and international trade or foreign relations. Technology students who show an interest in interdisciplinary studies should be encouraged in this direction.

SECTION 5

GOALS, OBJECTIVES AND BROAD FEATURES OF ENGINEERING TECHNOLOGY EDUCATION

Engineering technology education by definition must be more intimately related to engineering education than are other technological educational programs that also build upon mathematics and the physical sciences. This close relationship is essential because engineering technology education prepares engineering technicians and technologists to serve with engineers as part of the total technological enterprise that extends from planning to production and continuing service. The engineering technician and technologist must, therefore, understand the language of engineering--written, symbolic and graphic, must be able to interpret in material terms the results of engineering analysis or design, and must work effectively as a member of the total technological team. The engineering technologist often carries much responsibility for the achievement of the physical result that derives from creative engineering planning and design.

The Overall Educational Objective

Engineering technology education is designed to educate two-year, associate-degree engineering technicians and four-year, bachelor-degree engineering technologists either to assist engineers or to provide independently the support for engineering activities of a formulated or practical nature for which contingencies requiring decisions based upon full knowledge of the engineering design are uncommon. The essential content of engineering technology curricula--independent of length--must therefore be mathematics, basic science, technical science, and a technical specialty to a level consistent with the primary objective as stated, along with technical skills related to a particular area of engineering practice. As a corollary, technological curricula that train individuals to work in the fields of science, business, marketing, data processing, health or agriculture are usually not properly classified as engineering technology although overlapping objectives may exist.

In order to achieve the objectives of the ASEE Engineering Technology Study it is necessary to determine the primary characteristic or special quality that distinguishes the engineering technologist from the engineer on the one hand and from other kinds of technologists or technicians on the other.

The Central Objective of Engineering Education

In 1950, Dean S. C. Hollister made a useful contribution to the definition of an engineering curriculum by emphasizing as the controlling objective the design of machines, structures or processes (Hollister, 1950). Today we would add the design of "systems" including social and human elements. However, the word "design" is not free from semantic confusion. It is widely used in a different context in associate degree programs of "drafting and design". Hence we must distinguish between design based upon high level mathematics and science, involving analysis and synthesis, characteristic of the work of engineers, and "established" design, characteristic of the work of technicians or technologists, which follows codified procedures or is based upon a lower order of math-science and which considers primarily the elements of a system rather than the system as a whole.

In 1950 greater attention naturally was given to defining the border area between science and engineering education than between engineering and technology education because the latter seldom exceeded two years and was often only one year in length. Now we have added four-year engineering technology programs for a baccalaureate degree. However, it is obvious that these baccalaureate programs would not exist separately from engineering curricula if their goals and requirements were practically the same. Therefore, it is our objective to search out and state clearly the essential differences between engineering and engineering technology education particularly when they are of the same duration in academic years.

The Math-Science Background for Engineering Technology Education

The primary objective of any degree program in engineering technology must be defined by the content of the curriculum itself. An important factor for consideration is the college-level mathematics requirement. Admission to a technology program is commonly based upon one year less and in some areas two years less of high school mathematics than is admission to an engineering program. Also, the high school science requirement for admission to engineering technology typically will be less than that required for admission to a school of engineering. It follows that a technological curriculum at the college level may be expected to include a less rigorous math-science sequence than an engineering curriculum and to terminate at a lower math-science level. Its math-science level establishes for a technology program the instructor's approach to a group of courses listed in this study as "technical science". Such courses are taught with the emphasis upon applications or standardized solutions of common problems rather than the engineering approach which de-emphasizes formulas and channelized procedures.

Other Curricular Areas in Engineering Technology

When standardized calculation techniques are carried forward into design as a part of technology education, it is evident that the concept of overall engineering design based upon analysis and synthesis, which at times requires calculus and advanced mathematics, cannot be given attention. Hence, the design instruction of the engineering technologist involves carrying out established procedures of design. Thus he develops a sufficient understanding of engineering design so that he may carry engineering projects forward into practical production, operation, and later provide maintenance. The major technical specialty and related technical studies are the essential core of any engineering technology curriculum.

A goal of immediate usefulness of graduates to their employers is considered important in designing two-year engineering technology curricula and is also emphasized in four-year curricula. To this end a study of the use of equipment is a common characteristic of engineering technology programs. Also, communication skills require attention in all engineering technology curricula, and general or liberal education is an important objective at the baccalaureate level.

The study of supervision or management is seldom a central characteristic of engineering technology education. The engineering technologist often directs others, but the same is true of engineering and members of many callings. Attention to management even in four-year engineering technology curricula is limited to a small fraction of the curriculum (some five percent) by need for advanced courses in the technical specialty and required breadth of technical studies. Management is sometimes included as a small part of humanistic-social study, but it must not be permitted to displace required liberal studies. It follows that the study of management is a *desideratum* rather than an indispensable part of an engineering technology curriculum. This is in contrast to industrial technology programs for which a primary objective is training for supervision or management achieved by trade-off with the technical depth of the curriculum.

Summary: The Central Objective of Engineering Technology Education

This analysis has established the central purpose of engineering technology education to be support for the practical side of engineering achievement with emphasis upon the end product rather than the conceptual process. There are many overlapping areas but, in broad outline, the engineering technologist may be said to achieve what the engineer conceives. The technologist is usually a producer, the engineer is more often a planner. The technologist is valued as an expediter, the engineer is sought as an expert. The technologist should be

a master of detail, the engineer of the total system. Hence we may characterize engineering technology education as follows:

> In contrast to engineering education where capacity to design is the central objective, engineering technology education develops capacity to achieve a practical result based upon an engineering concept or design either through direct assistance to an engineer, in supervision of technically productive personnel, or in other ways.

Where the work of the technologist and the engineer are similar in kind they may be expected to differ in level because of the difference in level of mathematics, science and engineering science in their educational backgrounds. The development of new methods is the mark of the engineer. Effective use of established methods is the mark of the technologist.

SECTION 6

CHARACTERISTICS THAT DIFFERENTIATE BETWEEN ENGINEERING, ENGINEERING TECHNOLOGY AND INDUSTRIAL TECHNOLOGY EDUCATION

The first need is to define with clarity the field of engineering technology education with its two major terminal points of the associate degree and the baccalaureate degree. The key word involved is "engineering", an adjective used to distinguish the engineering technologist not only from such specialized professional groups as medical technologists but also to protect him from loss of identity in the broad field of industrial applications of technology. Because the distinguishing adjective is "engineering", it is necessary to affirm the most significant activities of the engineering profession to which the engineering technologist by name and by definition is closely related.

Engineering--A Creative Profession

Engineering has always been applauded as a creative profession. Ancient temples, bridges, aqueducts, medieval churches, and early skyscrapers represent a continuing sequence of creative accomplishments paralleled or followed by mechanical, electrical, chemical, aeronautical, nuclear and space achievements of fantastic brilliance. These are stars in the engineer's crown and no one doubts that there are many more to come. They also add luster to the technicians who contributed to each success. In an earlier age, creative technical achievements depended upon the genius or ingenuity of a single mind, a combination scientist-engineer-technician who was often master craftsman as well. Today, technological teams ranging from three or four individuals to hundreds may coordinate their efforts and pool their ideas to achieve a planned goal. The invention and production of new technical accomplishments are the responsibility of engineers. Supersonic aircraft, nuclear power plants and space exploration are examples. Scientists will contribute concepts, technologists conduct pilot experiments, technicians control quality, and craftsmen perform essential workmanship; but the creative application usually generates within the minds of engineers who bring together scientific knowledge and practical art to answer a need or produce a new product. The planning and organizational capabilities of engineers then contribute to the economical multiple output of such products for broad consumption, an equivalent engineering achievement.

The Scope of Engineering Curricula

The purpose of accreditation of engineering curricula should be to assure an education that will produce engineers who can create or who can plan, organize and manage highly sophisticated technical enterprises. Such training

may represent "overkill" for some who enter more standardized activities, but all who are educated as engineers should have the potential of contributing to society at the upper technological level which herein is termed creative engineering. It is necessary, therefore, that accredited engineering curricula include science and mathematics of considerable sophistication, at least through differential equations, and engineering science--in breadth to cover nearly all its areas and in depth for the area directly related to the curriculum major. In addition, humanistic and social studies are specified, not only as part of a liberal education, but also so that the engineer may communicate and work effectively with others and recognize the impact on society of his work. These objectives carried out in full measure would fill a four-year program of study allowing for a few elective courses of special interest to the individual. However, to develop his potential of creative accomplishment, the engineer needs appreciable study of synthesis or design including systems analysis and exposure to the art of engineering; or for some the opportunity to penetrate deeply into a limited area which mav initiate a career in research or development.

The subdivisions of the engineering curriculum as discussed above are inherent whether the time span is four or five or more years. These characteristics, therefore, define an engineering curriculum and may be used to differentiate it from one in either engineering technology or industrial technology, or more readily from an engineering technician program which is usually of about two years in length.

The Scope of Baccalaureate Engineering Technology Curricula

If a baccalaureate curriculum of engineering technology is to produce graduates who can work closely with engineers, and after adequate experience accept responsibility for production of engineering work, there must be considerable overlap between each engineering technology curriculum and the related engineering curriculum. The engineering technology mathematics requirement need not be as advanced as engineering mathematics but it must provide an adequate base for a realistic study of physics and chemistry. This will require a study of the elements of differential and integral calculus but not necessarily differential equations except for a field such as electronics. Even so, the courses in mathematics in the baccalaureate engineering technology curriculum will normally avoid some of the mathematical rigor considered necessary for engineers. In turn, this will influence the content of the engineering technology courses in physics and in technical science even though the titles correspond closely with comparable courses for engineers. It seems unlikely that the four-year engineering technology curriculum can provide time for more than a very limited approach to engineering analysis and design. The remainder of the curriculum will be needed to provide the engineering technologist with at least as broad a liberal education as is extended to engineering students, sometimes including the elements of supervision, and with a reasonably extensive coverage of the art of the field including production methods and equipment.

Associate-Degree Curricula in Engineering Technology

The accreditation criteria for associate-degree programs of education for engineering technicians have been developed by ECPD. As in the baccalaureate degree programs for technologists, the use of the adjective "engineering" requires a special thrust for associate-degree programs. The graduates of such educational programs must be technicians who are able to communicate easily with engineers and contribute to or carry out engineers' plans or designs. Even though the curriculum may be only two years in length, it will often require nearly as high a content of mathematics, science and technical science as a baccalaureate curriculum in engineering technology. Therefore, such two-year engineering technology curricula have a very limited content of non-technical studies. A growing number of institutions provide an opportunity for the successful associate-degree engineering technician to continue in a baccalaureate program for a bachelor's degree either in industrial technology or in engineering technology. The loss of credit or increase in overall time beyond four years will depend upon the objectives of the associate and baccalaureate programs. If curricula are designed for transfer or continuity there seems to be no necessary increase in time beyond four years. Percentage time distributions for two-year curricula are suggested in Section 7 of this report.

Community College Contributions to Engineering Technology

The wide diversification of technology programs in great numbers of community colleges assures that most of the conceivable variations in technical education exist. A few community college programs have met the criteria for accreditation by ECPD as engineering technology programs for the associate degree. However, it seems likely that the great majority may not achieve ECPD standards because the objective of close support of engineering works as contrasted to employment in a technical industry has not been emphasized in planning community college programs. Of course, other technical programs still further divorced from engineering technology exist in the vocational field. It is evident, therefore, that there is a great range of training objectives at the two-year technical level. Hence the use of the adjective "engineering" for associate-degree as well as for baccalaureate-degree curricula will have to be guarded by ECPD through its accreditation process if the profession of engineering is to have the high-level technician support that seems required by the advancing technology of the 1970-80 decade.

The Scope and Objectives of Industrial Technology Curricula

One interface of engineering technology education is with educational programs of industrial technology. As stated previously, industrial technology programs evolved within departments of industrial arts education where some continue, but others have independent existence in any one of several colleges.

Since the ASEE Study was not planned to survey curricula other than engineering technology it has been necessary to rely upon published material in order to delineate the boundary area between engineering technology and industrial technology. For this purpose a current and most useful study of industrial technology is the California State Colleges Report of 1970. An authorized abstract of this report, in considerable detail, has been reproduced herein, part D of Section 3. This abstract also provides considerable information applicable to engineering technology, including a useful industrial survey.

Definitions. It is useful to compare definitions of engineering technology and industrial technology. For engineering technology the accepted ECPD definition is as follows:

> Engineering technology is that part of the technological field which requires the application of scientific and engineering knowledge and methods combined with technical skills in support of engineering activities; it lies in the occupational spectrum between the craftsman and the engineer at the end of the spectrum closest to the engineer.

A key phrase for engineering technology is "in support of engineering activities".

Several interrelated definitions of industrial technology are quoted in the abstract of the California State Colleges Report in Section 3-D. For example:

> The graduate, through having knowledge of basic industrial skills, is oriented towards assisting and directing the development program, the flow of production, the distribution of the product, and other facets of general management. The technologist supervises operations involved in the development of a consumer product, or its movement to the distribution point, and even making it acceptable and popular on the open market. Some curricula offer variations in the business portion, permitting a sales emphasis, for example.

According to the National Association of Industrial Technology:

> The curriculum, even though built on technical education, has a balanced program of studies drawn from a variety of disciplines relating to industry. Included are a sound knowledge and understanding of materials and manufacturing processes, principles of distribution, and concepts of industrial management and human relations; experience in communication skills, humanities, and social sciences; and a proficiency level in the physical sciences, mathematics, design, and technical skills to permit the graduate to capably cope with typical technical, managerial and production problems.

The Principal Thrust of Industrial Technology Education

All educational programs are designed to achieve some goals or objectives. Educational programs considered occupational--including professional--define one of their principal goals in terms of some kind of employment or it may be more narrowly stated in terms of a particular job. The goals statement is an important characteristic that differentiates educational programs.

The key phrases for industrial technology education, according to the California State Colleges Report, are "occupying the mid-ground between engineering and business administration", and "emphasizing the applied aspects of industrial processes and personnel leadership". These objectives are sufficiently removed from "in support of engineering activities" to make necessary different curricular emphases in industrial technology from those of engineering technology. Both types of curricula vary over a wide range so that each is best described in terms of a "median curriculum". Also, the emphasis upon "breadth" in industrial technology, which contrasts with "specialization" in engineering technology, can best be described in terms of broad curricular groupings, such as math-science-technical content *versus* non-technical content including management.

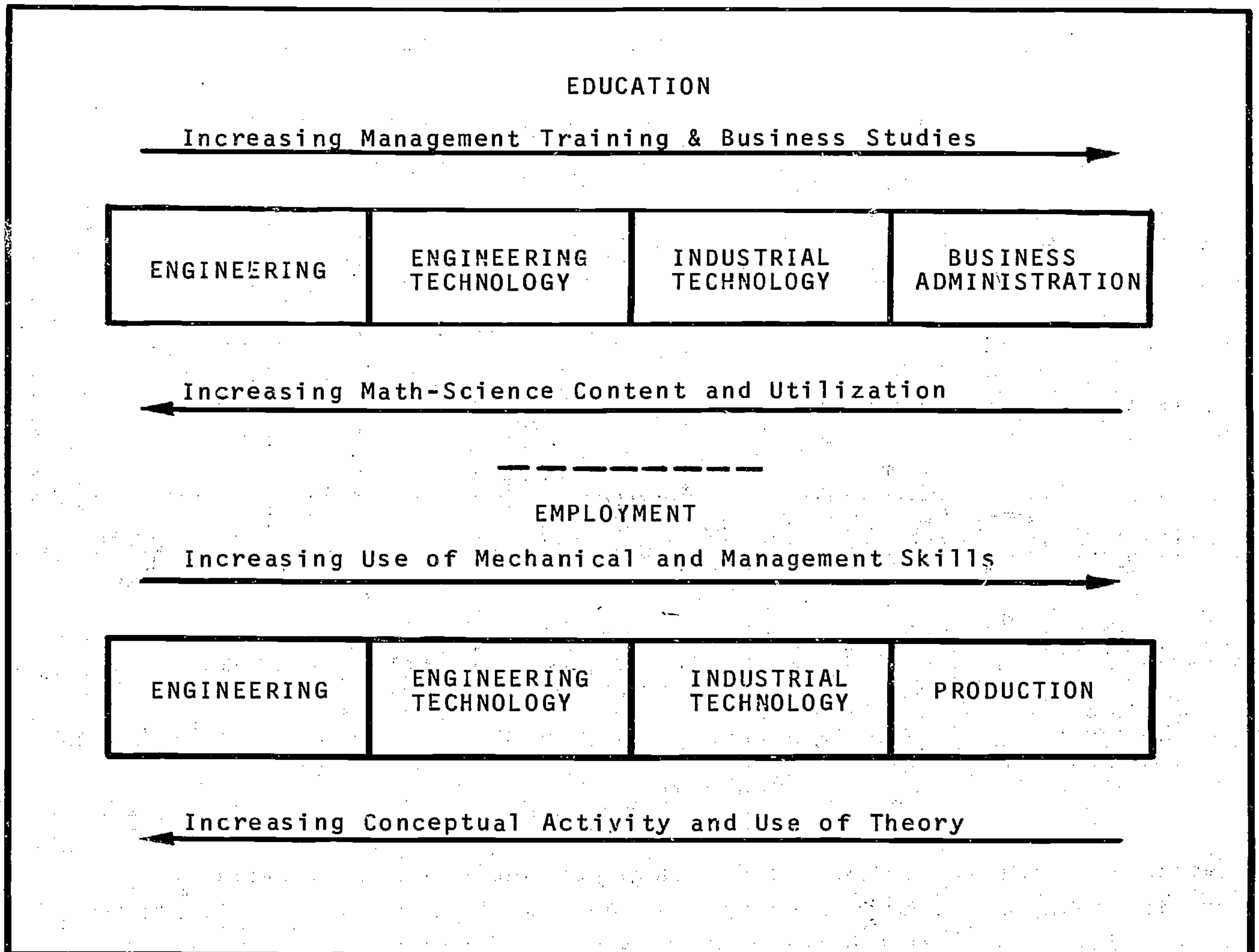
Charts that Present the Interrelationships of ET and IT Education

The logic of the analyses provided by the California State Colleges Study of Industrial Technology and the relative consistency of the responses to the industry questionnaire (summarized in Section 3-D) have led to ASEE's use of the CSC study as indicative of the development, status, and industrial acceptance at this time of industrial technology education. The CSC Study and its industrial survey fortunately also include sufficient attention to engineering technology for one to draw conclusions as to the relative position gradually being assigned both by educators and employers to IT *versus* ET education.

Figure 1 which accompanies this section has been prepared by the ASEE staff to illustrate graphically the interfacing, as suggested by the CSC Study, of industrial technology education and engineering technology education, and their external interfaces with engineering education and business administration. A corollary diagram of employment depicts the external interfacing of ET and IT with engineering practive and with production. The counterflow arrows on the education diagram illustrate "increasing management training and business studies" with movement toward the right and increasing "math-science content" with movement toward the left. Similar counterflow arrows on the employment diagram point out the "increasing use of mechanical and management skills" with movement toward the right and "increasing conceptual activity and use of theory" with movement to the left.

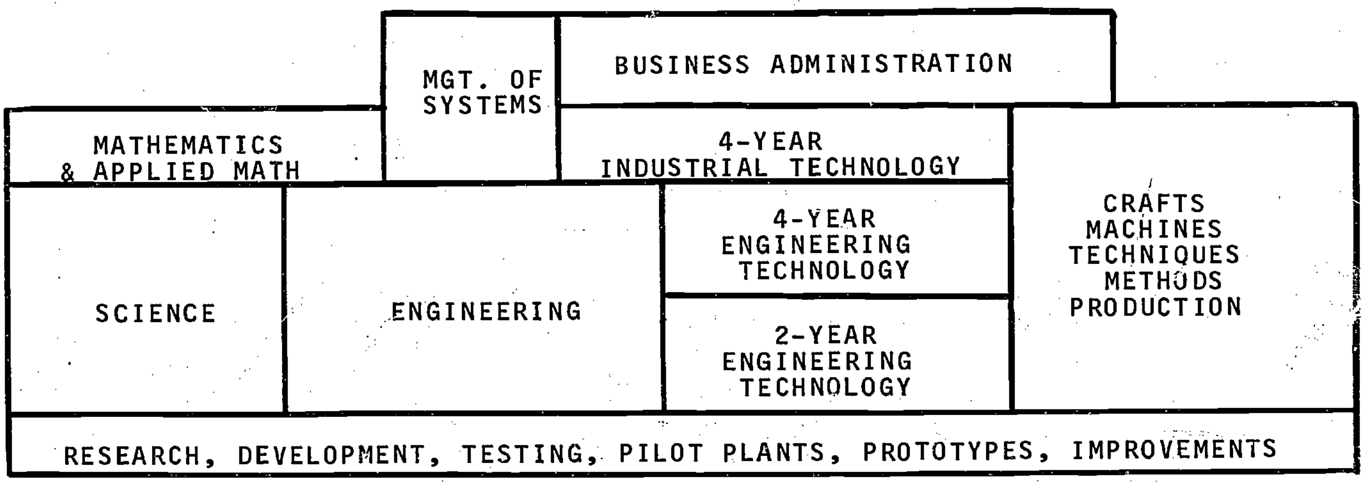
Figure 2 adds a number of additional interfacial relationships not possible on the simple diagrams of Figure 1. This diagram is to be read from left to right starting from pure science and moving through engineering into the technologies which finally interface with production. Note that science, engineering and systems management interface with mathematics, that industrial technology interfaces importantly with business administration and with engineering technology but less directly with engineering, and that business administration

FIGURE 1.--Interfacing of Engineering Technology With Engineering and with Industrial Technology



as well as industrial technology and engineering all interface with the management of systems although from different approaches. At the bottom of the chart it proved illustrative to list the steps of creative change initiated by research and development which interface at the left directly with science and engineering, followed by the steps of testing, pilot plant experiments and prototypes, and including more detailed improvements related to production shown at the right side of the diagram. There are, of course, many more interrelationships, but these would require a three-dimensional model for illustratio

FIGURE 2.--Major Interfacial Relationships in Technology Education and Employment[a]



[a]Note: This diagram is to be read from left to right. The vertical positioning of various blocks mearly illustrate interfaces. The entire diagram is properly viewed as being in the horizontal plane. Only *major* interfacial relationships are indicated; *each block bears at least some relationships to each other block;* also industry representatives emphasize that work assignments inevitably blur the interfacial boundaries shown.

Figure 3 presents for comparison purposes the "median curricula" for industrial technology and engineering technology. The curricula illustrated are not likely to be found in exact duplication in any college catalog. However, the IT curriculum approximates the median or mean suggestions of the CSC study, *50% math-science-technical content,* and in agreement with industrial preferences for breadth, *50% non-science including management.* The ET curriculum follows closely the recommendations of the McCallick Report (see Section 3-B) which gives more emphasis to technical specialization, *70% math-science-technical content,* and which agrees with the industrial responses in the CSC Report (see Section 3-D) of those companies that preferred a "specialized" curriculum, i.e., 45% of those responding to the CSC qustionnaire.

Separation of ET and IT Curricula for Accrediting

The preceding analyses appear to justify concepts that the educational goals of ET and IT curricula differ appreciably and that the central IT objective of "production management" *versus* the ET objective of "support for engineering activities" will be sufficiently reflected in baccalaureate educational curricula to require application of different criteria for accreditation.

FIGURE 3.--Typical Technological Curricula of Differing Objectives

INDUSTRIAL TECHNOLOGY (IT) Median Curriculum					(4-Years)	ENGINEERING TECHNOLOGY (ET) Median Curriculum				
Soc Sci	Non-Tech Elect	Tech Spcty	Tech Elect	Mgt Ind-Relat	4th Year	Soc Sci	Non-Tech Elect	Tech Spcty	Tech Spcty	Tech Elect
Human-ities	Tech Sci	Tech Spcty	Tech Genl	Mgt Acct	3rd Year	Human-ities	Tech Sci	Mgt	Tech Spcty	Relat Tech Study
Comm	Math -- Sci	Non-Tech Elect	Tech Genl	Mgt Econ	2nd Year	Comm	Math Tech Sci	Tech Sci	Tech Spcty	Relat Tech Study
Genl Educ	Math	Sci	Tech Genl	Non-Tech Elect	1st Year	Genl Educ	Math	Sci	Tech Core	Tech Core
Oriented Toward Production Management						Oriented to Support Engineering Activities				

Based upon curricula of 120 semester credit hours exclusive of Physical Education and ROTC

INDUSTRIAL TECHNOLOGY (IT)

Genl Educ, Comm, Humanities, Soc Sci, Non-Tech Elect	35%	42 Sem Hrs	50% Non Tech
Management, Econ, Acct, Ind Relat	15%	18 Sem Hrs	
Math, Sci, Tech Sci	20%	24 Sem Hrs	50% Tech
Tech Genl, Tech Spcty, Tech Elect	30%	36 Sem Hrs	
TOTAL	100%	120 Sem Hrs	

ENGINEERING TECHNOLOGY (ET)

Genl Educ, Comm, Humanities, Soc Sci, Non-Tech Elect	25%	30 Sem Hrs	30% Non Tech
Management	5%	6 Hrs	
Math, Sci, Tech Sci	25%	30 Sem Hrs	70% Tech
Tech Core, Tech Spcty, Relat Tech, Tech Elect	45%	54 Sem Hrs	
TOTAL	100%	120 Sem Hrs	

If, as seems reasonable, institutional individuality can be expressed adequately within the major subdivisions of (1) math-science-technical studies and (2) non-technical studies including management, a clear-cut accrediting operation can be achieved. The real distinction between an IT math-science-technical content of about 50% *versus* an ET math-science-technical content of approximately 70% can be the main curricular criterion for separating these related educational areas. Much flexibility should then be permitted within these broad curricular subdivisions because of the diversity of employment opportunities open to each category of technologist.

The goals statement and curricular content are not the only criteria for distinguishing related educational programs. The interests and aptitudes of students, the educational experience backgrounds of the faculty, and the specialized laboratories and equipment needed for proper instruction are equally important criteria. These will be discussed as factors that can also contribute to program differentiation.

Student Differentiation

One would anticipate a measurable difference in the mean scores of entering engineering and technology students on mathematical aptitude and achievement tests. To the extent possible with available test data, such student differentiation will be reported in later sections. However, it is equally important to emphasize that each student group is represented by a distribution curve of wide coverage. For example, mathematical aptitude distribution curves for (1) engineers, (2) engineering technologists, (3) industrial technologists, and (4) two-year engineering technicians are certain to overlap greatly. Even the lowest group on a given test will probably contain individuals having higher scores than some individuals in a higher scoring group. Another student characteristic, that of a feeling for or interest in machinery and equipment, may serve as a second distinguishing factor when adequate data become available on mechanical aptitude tests.

Faculty Differentiation

Faculty characteristics provide an important means of distinguishing between the purposes of educational programs in the several technological categories. Essentially all teachers above the rank of instructor in schools of engineering possess master's degrees and a majority hold Ph.D.'s. New additions to the faculty will be heavily Ph.D.'s or doctorates in engineering because of research orientation. Faculties for baccalaureate programs in engineering technology should have a majority of engineers with practical experience relevant to the curriculum. Programs in industrial technology are less dependent upon engineers for instruction and may be staffed largely by majors in industrial arts and practitioners from industry including some who have had management training or experience. Faculties of 2-year technician

education programs are more mixed in character and depend upon the uniqueness of the program. It seems probable that faculty differentiation can and should be a major factor in distinguishing between the four areas of technical education being considered here.

Types of Laboratories Required

With some exceptions laboratories in engineering show a strong orientation toward experimentation or research, an emphasis not as important in other areas of technological training. Some engineering laboratories are used for the training of engineering technologists, and even more of such exchange seems useful because the engineering technologist must be prepared to work closely with engineers. Such relationships are less likely to be feasible in the education of associate-degree engineering technicians. Perhaps an ideal arrangement would be for the baccalaureate engineering technologist to gain a part of his laboratory training in engineering laboratories and a part in production laboratories so that he might bring to the technological team an understanding of engineering experimentation and a knowledge of practical production techniques. Laboratories designed exclusively for engineering or industrial technology education may provide working models or actual production equipment not commonly included in engineering laboratories. Of course, measuring devices and testing equipment lend similarity to laboratories having quite different purposes.

Names of Curricula and Degrees

As of now (1970) very little influence for standardization of names or designations of technical curricula, programs or degrees has occurred. In this report the titles engineer, engineering technologist, industrial technologist and engineering technician are related to education programs defined in terms of length, faculty, students, facilities and curricula. Section 3-C has reviewed recommendations on terminology from previous reports. Without doubt, there are some educational programs designated in college catalogs as engineering technology that would be defined here as industrial technology, and conversely. The term engineering technology as a curriculum designation is also used for both two-year and four-year programs, a practice which will continue to be somewhat confusing. However, the graduates are usually classified as technicians (two-year) or technologists (four-year) according to the length of the educational program and the degree awarded. Employers use their own classification systems.

No analysis was made of the names of degrees awarded to engineers, technologists or technicians. The names of degrees are determined by historical planning or accident and are a jealously protected privilege of each institution. Efforts to develop a logical sequence of named degrees for the field of engineering have all failed. There is not likely to be any more standardization of

titles of degrees awarded to technologists. The objective here is to define educational boundaries or guidelines, not to attempt to control, standardize or even influence terminology.

SECTION 7

CHARACTERISTICS OF ASSOCIATE DEGREE CURRICULA IN ENGINEERING TECHNOLOGY

Institutions Offering Associate Degree Engineering Technology Programs

There exists no authoritative list of institutions which offer associate degree curricula in engineering technology. A number of recent publications, however, provide data from which reasonable estimates may be made. In 1969, the Engineering Manpower Commission conducted a survey to determine the number of associate degrees awarded in technology; the report of this survey stated that 394 institutions had made associate degree awards during the 1968-69 academic year (Alden, "Technology Degrees", 1970). Earlier, the National Center for Educational Statistics of the U.S. Office Education had furnished data in a different format, suggesting that during the 1967-68 academic year approximately 450 institutions made "formal awards" (these awards included both certificates and associate degrees) to students completing programs "at the technician or semiprofessional level" (NCES, "Associate Degrees..." 1969). And more recently, the Engineering Manpower Commission has published data on the Fall 1969 enrollments in institutions offering technician and/or pre-engineering programs (EMC, "Enrollments," 1970) which indicate that 558 institutions are engaged in this activity. Combining the two lists of institutions reporting to the Engineering Manpower Commission with the list reporting to the National Center for Educational Statistics is believed to produce a list of acceptable accuracy. The combined list contains 563 institutions. These institutions offer approximately 1600 individual curricula.

Thus, approximately 560 institutions offer nearly 1600 different two-year programs in the general field of engineering technology. There are, doubtless, variations in the scope, level and emphasis of these offerings, but all purport to prepare "semi-professional" workers in technical fields related to engineering practice.

The institutions offering educational programs in engineering technology are of various types. They belong primarily to one of the following classifications:

1. *Monotechnical Institutes*.--Single purpose institutions having engineering technology education as their sole institutional objective.

2. *Polytechnical Institutes*.--Institutions with a variety of objectives related to technical and occupational fields, including programs related to business, health, or public service as well as to engineering.

3. *Comprehensive Community Colleges*.--Community and/or junior colleges which include in their offerings various occupational-technical programs

as well as "university parallel" or "transfer" programs.

4. *Universities*.--Senior institutions (universities, colleges, or other, regardless of the actual name of the institutions) which include associate degree programs in engineering technology as part of their offerings, either on the main campus or at a branch campus.

The largest proportion of enrollments is found in the comprehensive community colleges, although curricula having accreditation by the Engineers' Council for Professional Development are found to the greater proportion in monotechnical and polytechnical institutes.

Table 2 summarizes some of the general characteristics of the approximately 560 institutions which offer associate degree engineering technology curricula.

TABLE 2.--General Characteristics of Institutions which Offer Associate Degree Engineering Technology Curricula

Item	Comments
Control	86% public, 14% private
Type	87% are two-year institutions 13% are universities or four-year colleges which include associate degree curricula in their offerings
Emphasis	10% offer engineering technology only 13% offer a variety of technical programs but deal only in technical education 64% are comprehensive community colleges 13% are senior colleges or universities
Accreditation	11% have at least one curriculum accredited by the Engineers' Council for Professional Development 92% are accredited by the appropriate regional accrediting association
Comprehensiveness Of Offerings	80% offer four or fewer engineering technology curricula 20% offer more than four engineering technology curricula
Frequency Of Offerings	Electrical/Electronics Technology is offered most frequently (30% of the total curricula, 50% of the institutions, and 25% of the associate degrees awarded) Mechanical Technology is second in frequency of offering (12% of the total curricula, 25% of the institutions, and 13% of the associate degrees awarded)

The Associate Degree Engineering Technology Curriculum

Associate degree engineering technology curricula, although they differ from one another in certain respects, have many characteristics in common. For example, a recent study of a selected national sample of 120 such curricula revealed the existence of a basic *structural profile*, that is, a common pattern of curriculum structure based on the number of semester hour credits required in various curricular areas. The 120 curricula studied were identified as programs of quality which were perceived to have potential influence on the future of engineering technology education. Subsequent data tables and figures in this chapter are all based on this sample of curricula.

Findings from a Study of 120 Associate Degree Engineering Technology Curricula

The primary purpose of the study just mentioned was to discover the extent to which various subject matter areas were treated in associate degree engineering technology curricula. The definitions of curricular areas used for the purposes of the study are as follows:

> *Technical specialty.*--Technological subject matter content in an engineering technology curriculum in which a student concentrates study; the "major" of a curriculum. For example, technical specialty subject matter in an electrical technology curriculum usually will include college courses entitled "electrical machinery", "transmission networks", "microwaves", and the like.

> *Related technical studies.*--Technological subject matter content in an engineering technology curriculum related to an area of technology or to the development of skills to support a technology, but not directly related to the area of specialization; courses which support the major. Basic electronic circuits taught to mechanical engineering technology students is one example; introductory drafting is another.

> *Technical sciences.*--Subject matter content in an engineering technology curriculum having its roots in mathematics and basic science but carrying knowledge further toward applicability; courses designed to supply the core of technological knowledge the student needs in his chosen profession. While more limited than the "engineering science" of a professional engineering curriculum, the same areas are included. For example, the technical sciences include such subjects as "applied mechanics", "strength of materials", "fluid flow", and the like.

> *Physical sciences.*--Chemistry, physics and integrated courses in chemistry and physics.

> *Mathematics.*--Subject matter content beyond the level of "intermediate algebra"; "college algebra" and other mathematics subjects including trigonometry and calculus which have college algebra as a co- or prerequisite.

> *Communications.*--Subject matter content related to grammar, rhetoric, speech, technical writing, and other phases of language except literature.

> *Humanities/Social Studies.*--Subject matter content related to literature, the arts, philosophy, history, sociology, political science, and the like.

Other studies.--Subject matter content in a curriculum not classifiable under one of the preceding categories; these include R.O.T.C., physical education, life science, foreign language, and "free electives" not identifiable by category.

Table 3 summarizes the structural characteristics found for the sample of associate degree engineering technology curricula in terms of the number of semester credits typically required in each of the curricular areas just defined. The table lists the range of requirements found to exist in the 120 curricula studied, the mean (arithmetic average) of these requirements, and the mode (highest frequency) of the requirements; the mean has been adjusted to the nearest half-credit for convenience in reporting.

TABLE 3.--Structural Characteristics Found in a Sample of 120 Associate Degree Curricula in Engineering Technology[a]

Curricular Area	Semester Credits Required		
	Range	Mean[b] (Arithmetic Average)	Mode (Highest Frequency)
Technical Specialty	8-24	23	24
Related Technical Studies	0-22	8	8
Technical Sciences	0-22	7	8[d]
Physical Sciences	4-18	7	8
Mathematics	4-14	8.5	10[e]
Communications	3-12	6	6
Humanities/Social Studies	0-15	7	6
Other	0-14	2	2
Total Technical Studies[c]	24-51	38	40
Total Curriculum	60-83	71	72

[a]See page 51 for definition of sample

[b]Adjusted to nearest half semester credit.

[c]Includes technical specialty, related technical studies and technical sciences.

[d]High frequencies at 0 and at 4 semester credits were also noted.

[e]High frequency at 6 semester credits was also noted.

Figure 4 gives some insights into the kinds of structural variations and central tendencies which existed in the group of curricula on which Table 3 was based. Figure 5 displays graphically the structural profile of these engineering technology curricula in terms of modal credit hour requirements.

FIGURE 4.--Distribution of Semester Credit Requirements in Selected Curricular Areas in 120 Associate Degree Engineering Technology Curricula

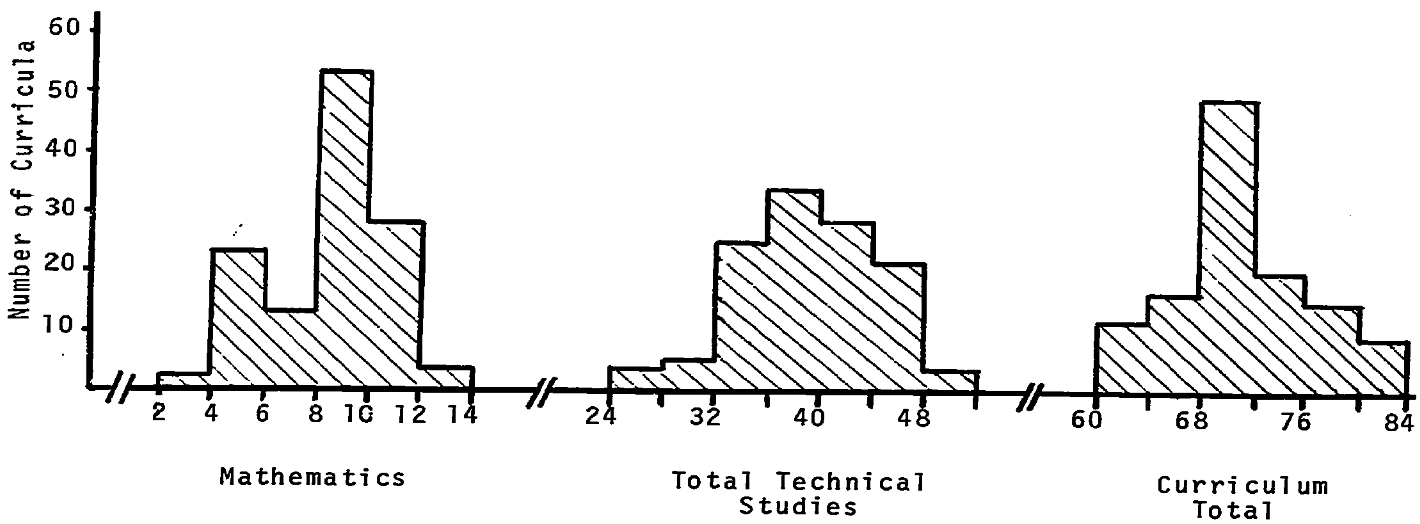
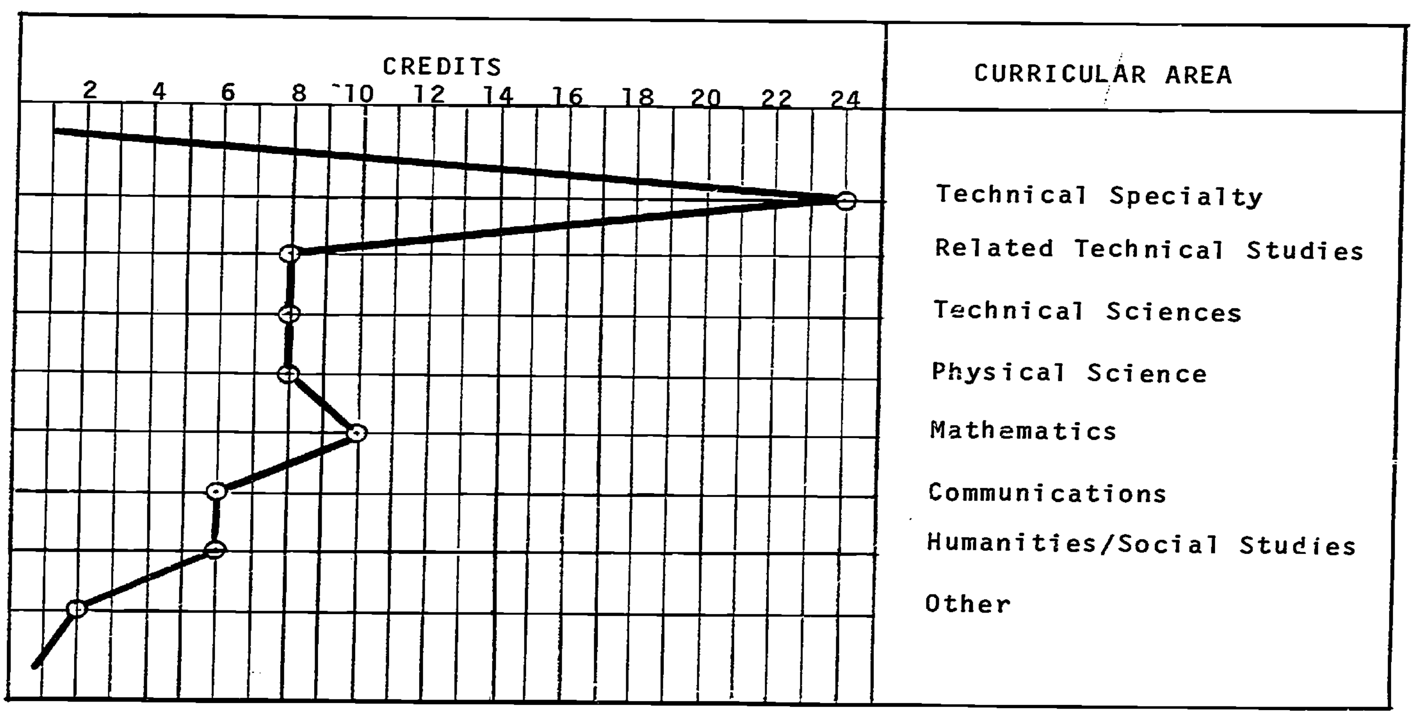


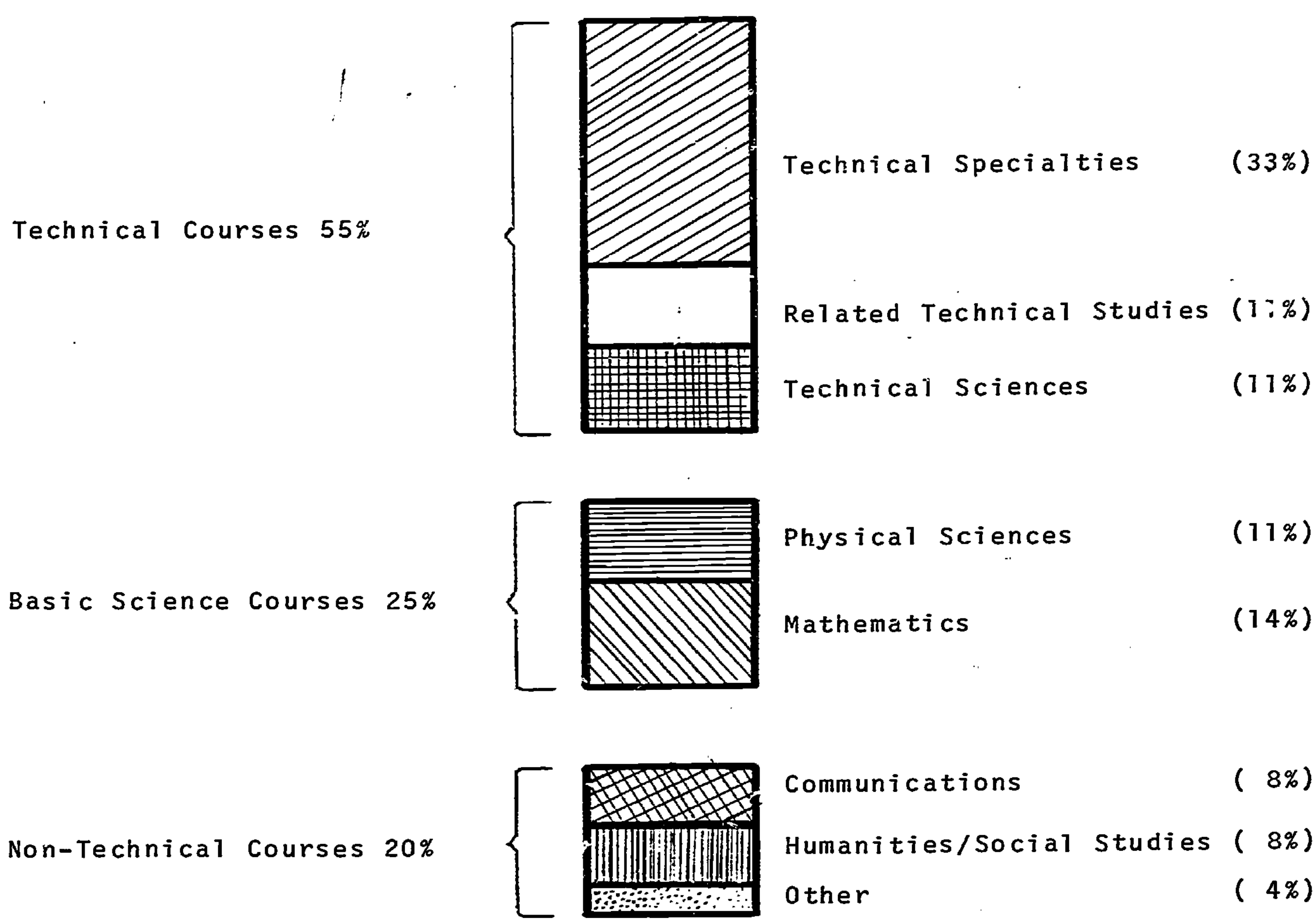
FIGURE 5.--Modal Structural Profile Found for a Sample of 120 Associate Degree Engineering Technology Curricula



Total Credits in Typical Curriculum=72 sem. hrs.; Total Technical Credits (Technical Specialty, Related Technical Studies, Technical Sciences)=40 sem. hrs.; Total Math-Science-Technical Content=58 sem. hrs. or 80% of curriculum.

The mode was used on this diagram because it is the more useful statistic to describe usual practice and has the advantage of easy interpretation in terms of the credit values normally assigned to college courses. Three major content areas in the curriculum can be identified. These are the *technical courses* (including technical specialties, related technical studies and technical sciences), *basic science courses* (including mathematics and the physical sciences), and *non-technical courses* (including communications, humanities and social studies, and other such content). Figure 6 shows the proportion of the curriculum typically devoted to each of these major areas and to their components. Associate degree engineering technology programs, even though they may vary somewhat among themselves in their emphasis within the three

FIGURE 6.--Distribution by Major Content Area of Required Credits in a Sample of 120 Associate Degree Engineering Technology Curricula



major areas, are highly consistent in their pattern of distribution of required credits into these major curriculum areas. It is noted that the total nontechnical content is restricted to 20 percent, leaving 80 percent for the math-science-technical content of the curriculum.

The curriculum structures of associate degree engineering technology programs often agree in detail as well as in the general distribution of credits into the technical, basic science and nontechnical areas. Examination of individual curriculum outlines as published in institutional catalogs or bulletins reveals that many associate degree engineering technology programs have profiles which trace major sections of the modal profile shown in Figure 5. One possible explanation for inter-program consistency can be offered. ASEE's *Characteristics of Excellence* (the "McGraw Report") had, in 1962, suggested certain guidelines for the structure of engineering technology curricula. An illustrative curriculum was presented, showing a possible distribution of course credits in certain curricular areas[1] (see page 10, herein). That suggested distribution is shown in Table 4, together with corresponding data for the curricular areas of the modal engineering technology program discussed above. (Editorial revisions have been made both in the terminology used in the McGraw Report and that previously used here in order to facilitate comparison.) Examination reveals a high degree of correspondence between items in the table; the 1962 McGraw Report has evidently had an appreciable directive influence on the evolution of associate degree engineering technology education programs.

TABLE 4.--Distribution of Credits in McGraw's "Illustration" and in the Modal Associate Degree Engineering Technology Curriculum

Curricular Area	Semester Credits: Suggested by McGraw, 1962		Semester Credits: Modal Program, 1970	
Total Technical Studies	39		40	
Physical Sciences	6	57	8	58
Mathematics	12		10	
Communications	6		6	
Humanities/Social Studies	6	15	6	14
Other	3		2	
Curriculum Total	72		72	

Curricular Differences in Programs

Individual associate degree engineering technology programs sometimes have curriculum structures which deviate from the modal pattern. In the sample of curricular studied, certain factors seem related to variances in structural profiles.

One factor which can be associated with such variance is the *institutional setting*--monotechnical institute, polytechnical institute, comprehensive community college, university--in which a curriculum is offered. The curricula found in monotechnical institutes, polytechnical institutes and universities have quite comparable structures; however, curricula in comprehensive community colleges generally differ from the others in certain ways. First, community college programs tend to be shorter, requiring fewer total credits for the associate degree. Secondly, community college curricula generally list fewer requirements in the math-science, the technical, and the humanistic-social areas. And finally, community college curricula usually permit more credits to be earned as free elective or "other" content.

The *technical discipline* on which the curriculum places emphasis is another variable influencing curriculum structure of associate degree engineering technology curricula. For example, electrical technology curricula are likely to require a greater proportion of their credits in mathematics and the technical specialty than are mechanical technology curricula; the latter, on the other hand, generally have substantially higher requirements in the "related technical studies" area than do electrical technology curricula, even if offered at the same institution. Variations of this nature are not unexpected.

Curriculum Trends and Comments

Several curriculum trends in associate degree engineering technology education programs seem worthy of note. These trends are related to an increasing sophistication and complexity of the technological environment and they may have important implications for future developments in engineering technology education.

First, subjects with titles such as "introduction to computers", "computer programming", "applications of data processing", and the like are beginning to appear in the published curriculum guides for engineering technology programs. This trend, it is believed, is a reflection of the needs of the contemporary era and a healthy sign that engineering technology education is responding to those needs. The use of computers is expected to become increasingly important in modern life, especially relevant in the technological domain. Hence, formal coursework in appropriate basic elements of computer usage is expected to become an identifiable, integral part of most associate degree engineering technology curricula of the future.

A second trend, evident in the published curriculum guides of many associate degree engineering technology programs, is the separate identification of coursework belonging to the "technical sciences" area. The classification, in fact, has been used throughout this document, for the trend has seemed clearly established; the McGraw Report and other earlier literature, however, did not use this curricular area as a separate category. It is believed that the contemporary technological environment requires of the practitioners in its technology a broad base of technical information which will not quickly become obselescent; although specialization to prepare him for immediate productivity is required of the engineering technician, he must also remain technically viable for a reasonable period beyond his initial employment. Such viability can, it is believed, be enhanced by breadth in the preparatory curriculum--specifically, by formal study of mathematics, the physical sciences, and the several technical sciences related to the various general fields of engineering practice. Associate degree engineering technology curricula seem, in general, to treat mathemathics and the physical sciences adequately, but some weaknesses are perceived in the coverage of the technical sciences. It is expected, therefore, that engineering technology curricula will evolve in such a manner that the proportion of time devoted to the technical sciences will increase--not, however, at the expense of requirements in mathematics and the physical sciences--and that more attention will be given to this important curricular area.

A third discernable trend in associate-degree engineering technology curricula is a reduced emphasis on skill courses. Published curriculum guides show such subjects as "machine shop", "welding", "wiring", and the like to a lesser extent than earlier had been the case; a course in drafting, however, remains a part of most curricula.

Criteria for Two-Year Engineering Technology Curricula: An Addendum to the McGraw Report of 1962

Because of the three major curriculum trends just discussed and because of the preceived nature of the technological environment of the next decades, it seems desirable to restate the curriculum summary of the McGraw Report in current terminology. The curriculum summary here may be compared with the original McGraw summary given previously in Section 3-A.

The curriculum has been divided into three areas of subject matter, somewhat consistent within each section.

(a) *Technical courses*, which include the major technical specialties, related technical studies and the technical sciences.

(b) *Basic science courses*, which include mathematics and physical sciences.

(c) *Non-technical courses*, which include communications, humanities, social sciences and other life-oriented courses.

Table 5 summarizes the minimum 60-semester-hour recommendations of this report along with an illustration of their possible application to a 72-hour curriculum. *It should be emphasized that the 72-hour program shown is an example only and should not be interpreted as a requirement or as an ideal. Many variations are possible.* However, institutions should view with concern any curriculum which meets only the minimum requirements shown. Variations above the minimum are not only expected but desirable.

TABLE 5.--A Suggested Curriculum Guide for an Associate-Degree Curriculum in Engineering Technology, an Addendum to the McGraw Report of 1962

	CURRICULUM SUMMARY IN SEMESTER CREDITS	
TECHNICAL COURSES	MINIMUM	ILLUSTRATION
Major Technical Specialties (e.g. courses in technology major) / *Related Technical Studies* (e.g. technology support to major	21	27
Technical Sciences (e.g. topics from Engr. Science areas)	9	12
	30	39
BASIC SCIENCE COURSES		
Mathematics (e.g. algebra, trig., calculus)	9	12
Physical Sciences (e.g. Physics, Chemistry	6	6
	15	18
NON-TECHNICAL COURSES		
Communications (e.g. English Comp. Speech, Report Writing)	6	6
Humanistic-Social Studies (e.g. Economics, Literature, History)	6	6
Other (e.g. management, human relations, or additional humanistic-social studies)	3	3
	15	15
TOTALS	60	72

SECTION 8

SURVEY OF BACCALAUREATE ENGINEERING TECHNOLOGY PROGRAMS

History

While baccalaureate educational programs based on mathematics and science and designed to produce graduates for industrial employment date back at least to 1923, those designated as baccalaureate engineering technology programs were developed primarily in the last two decades.

To encourage experimentation, an ECPD committee made the following recommendation which ECPD adopted in 1966: "ECPD accreditation is based on compliance with minimum criteria established for curricula of not less than two academic years' duration. These criteria are applied regardless of the total length of the curriculum beyond the two academic years and, thus, are applicable to curricula which may lead to either the associate or the baccalaureate degree." The procedure of using the same criteria for technology programs of varying length is consistent with the procedure for evaluating engineering programs of varying length. The same criteria for engineering curricula have been applied to first degree programs whether they are four- or five-year baccalaureate or master's degree programs.

Currently Accredited Programs

The first baccalaureate engineering technology curricula were accredited by ECPD in 1967. By 1970, twenty-seven curricula in twelve institutions were accredited by ECPD. In addition, ten curricula at three other institutions have received "early recognition" by the Engineering Technology Committee as candidates for accreditation, or have reasonable assurance of accreditation when all criteria are met.

Characteristics of Accredited Programs

The intent of ECPD was to permit rather wide diversification in baccalaureate programs and to provide for further development without constriction by limiting criteria. It now may be helpful to analyze the characteristics of the current baccalaureate programs which were accredited on the basis of published criteria for technology programs of two or more years in length.

The data for this analysis were obtained from catalogs and other published material, visits to the campuses of some twenty institutions, and from specially compiled data furnished by these institutions. In addition, data were obtained in the same manner from a selected group of non-evaluated and, therefore, non-accredited institutions to permit comparisons between accredited and non-accredited curricula.

Curricular Comparisons

When ECPD decided in 1966 to evaluate and accredit baccalaureate technology programs, it was anticipated that several types of educational programs might develop and, at a later date, a selection might be made of the most successful. However, the accredited and the non-yet-accredited but apparently accreditable engineering technology curricula are remarkably similar. Essentially, all curricula utilized the additional two years for (1) greater specialization in a particular technology and (2) inclusion of some general education courses. Some of the general courses are frequently required by the institution for all baccalaureate graduates.

The curricula range in length from about 124 to 135 semester credit hours, with an average of about 130 hours. Associate degree curricula range from 60 to more than 80 semester credit hours with an average of nearly 70 hours. Thus, a baccalaureate curriculum requires about an additional 60 semester credit hours above the associate-degree program. Within this constraint, and after providing courses for some greater depth or breadth in the technical specialty and related technical courses, and the addition of required general education studies, there is little opportunity for a concentration of other courses, such as in business or management.

Mathematics

An accredited engineering technology curriculum has 12 to 15 semester credit hours of mathematics consisting of a course in algebra, one in trigonometry, and two courses in analytic geometry and calculus. In addition there may be a course in computer science, statistics, or an additional advanced math course for some technical speciality, such as electronics, that requires a stronger math background. Approximately one semester or about 12% of the curriculum is devoted to mathematics.

The algebra and trigonometry courses are quite likely to be the standard courses taken by all students. The analytic geometry and calculus courses are likely to be "applied" and developed especially for the technical students. It is not to be expected that these courses are taught with the same rigor or insistence on development of theorems and proofs as the calculus courses taught for engineering students.

Additional concepts of mathematics may be taught in the technical science and technical specialty courses. Again, this is particularly true for electronics curricula, the most popular of all technology programs.

Physical Science

The requirements in basic science range from eight to twelve semester credit hours or about six to ten percent of the curriculum. Generally included

are two courses in physics taught with an algebra base and typical of physics courses taught for students other than those in physical science and engineering. Chemistry is frequently, but not always, required and is generally a single introductory course with a laboratory. This course, like the physics courses, is generally not developed or taught for technology students alone and includes students in the non-science disciplines in other fields of study.

Technical Science

It is more difficult to identify the technical science portion of a curriculum, for these concepts may be included in courses in the technical specialty and related studies. Technical science, like engineering science, has its roots in mathematics and basic sciences. ECPD criteria for engineering curricula defines engineering sciences as follows:

> Engineering sciences have their roots in mathematics and basic sciences but carry knowledge further toward applicability...in engineering analysis, design and synthesis. (ECPD, 1969, p. 64).

The report of the Committee for the Development of Guidelines for Evaluation and Accreditation of Four-Year Programs in Engineering Technology Education, defined technical sciences in these words:

> In these courses the technologist learns the theoretical characteristics and properties of devices, systems, structures, and processes, as well as the appropriate methods of analysis... mechanics, electric curcuit theory, fluid mechanics, thermodynamics, etc...

Technical science courses may have the same or similar names as engineering science courses, but the content cannot be the same because of the difference in the amount and the level of mathematics and basic science in engineering and engineering technology.

An engineering technology curriculum will often contain three courses, nine semester credit hours, or about 7 percent of the total credit hours, in technical science. These courses are frequently limited to those that have direct applicability to the technical specialty. Breadth of coverage does not appear to be one of the objectives of engineering technology curricula. Additional technical science may be included in the technical specialty courses, but it is doubtful that the technical science content of most accredited baccalaureate curricula is equal to 15 percent as recommended by the McCallick Report (see page 13, herein).

Technical Courses

The technical courses are designed to develop the ability to utilize mathematics, basic science and technical science knowledge and methods combined with technical skills in a particular field of technology.

Technical specialty courses consist of those in the technical major, e.g., electronics; related technical studies support this technical major, e.g., mechanical courses taught for an electronics major, or may develop technical skills, e.g., drafting.

Total semester credit hours devoted to the technical specialty and related technical studies range from about 40 to 55 hours, or from 30% to 42% of the curriculum. Curricula which have the lower percentage in technical specialty and related technical studies usually have a higher percentage in technical science and conversely. The difficulty of separating these areas of the curriculum suggests it may be more meaningful to combine technical sciences, technical specialties and related technical studies into one category of courses that constitute about 55 to 65 credit hours, or from 42% to 50% of the program.

General Education and Other Studies

The remainder of the typical currently accredited curriculum consists of about 25 semester credit hours, or about 20%, of general studies including communications and socio-humanistic studies; and about 20 semester credit hours, or 15%, of other specified non-technical subjects and/or technical electives.

Summary of Curricular Subdivisions

In summary, a typical accredited baccalaureate engineering technology program consists of the following:

Subject	Semester Credit Hours	Percent of Total Hours
Mathematics	15	12%
Basic Science	10	8
Technical Science, Technical Specialty and Related Technical Studies	60	45
General Studies	25	20
Other Specified Non-technical courses and Technical Electives	20	15
TOTAL	130	100%

Technology curricula not accreditable by current ECPD criteria generally contain less mathematics, in many cases only one-half as much, about the same amount of basic science, considerably less technical science and somewhat more

technical specialty and related technical courses. The additional technical courses are frequently designed to develop a higher order of technical skill, such as drafting. The other specified courses, which may constitute 20% to 25% of the curriculum, are likely to be mainly business and management courses.

Faculty Differentiations

The characteristics of the current faculty at institutions with accreditable engineering technology curricula vary widely from institution to institution. In the long run, many educators believe the kind, level and quality of educational programs are directly related to the characteristics of the faculty who design the curricula and teach the courses. A former chairman of the Engineering Education and Accreditation Committee of ECPD stated it more succinctly: "In accreditation, one evaluates the faculty and criticizes the curricula."

The faculty of these relatively new programs in technology also tend to reflect the origins of the program. If the background was Industrial Arts Education, many faculty members will have education degrees including some doctorates. If the program grew from a former technical program or vocational-trade program, some of the faculty will be craftsmen without collegiate degrees. If the technology program is closely allied to or was split from an engineering program, many of the faculty will be engineers with B.S. and M.S. degrees. Newer members of the faculty may have a B.S. in technology and an M.S. in technical education. There are nearly always a few faculty members with degrees in mathematics, physics, chemistry or other sciences.

Because engineering technology curricula are designed to produce technologists "in support of engineering activities", some engineers are considered essential to teach the technical science and technical specialty courses. The 1962 report, *Characteristics of Excellence in Engineering Technology Education*, states: "It is the Committee's opinion that approximately half the faculty members teaching the technical specialties should be graduate engineers or the equivalent." This recommendation, which is not a part of current ECPD criteria, has not been followed by all institutions with accredited engineering technology curricula. However, it is noted that recent hires by the institutions tend to be heavily weighted with engineering graduates. Thus one may expect this recommendation to be achieved within the next several years. The engineering "flavor" of a technology curriculum appears to be a result of engineering faculty members, because other technology programs taught by faculty without engineering degrees are different.

Strengthening of Faculties

The "Excellence" report cited above also states: "A significant proportion of the faculty must have relevant industrial experience, reasonably current."

A review of the biographies of the faculty from some of the institutions without a long technical tradition discloses that this recommendation is sometimes more a hope than a realty. It should receive increased consideration.

The level of education of the faculty in engineering technology programs is typically the master's degree. Doctorates in education are not unusual, and a few engineers with doctorates have been employed in the past several years. The recent decline in offers of employment to new doctorates in engineering and the reductions in engineering manpower in some industries may increase the number of technology faculty with advanced degrees in engineering: Those holding B.S. degrees in engineering, science, or mathematics frequently complete their master's degree in education.

Students' Aptitudes

The accredited baccalaureate engineering technology programs for which data were available attracted students with about the same range of academic aptitudes, measured by standardized tests, as other college freshmen and transfers. As a whole, technology students suffer by comparison in academic aptitudes only when measured against engineering students.

While the average score varied slightly from institution to institution, the mean score of the averages of entering students of all institutions was about 22 on the American College Testing (ACT) program or about 1000 on the Scholastic Aptitude Testing (SAT) program. Entering engineering students at some of these same institutions had a mean score of about 25 on ACT or about 1100 on SAT. One implication of test scores of entering engineering technology students that places them with the average of all entering students in the institution is their apparent ability to successfully complete standard or all-university courses in mathematics, science, communications, and socio-humanistic subjects.

The academic potential of entering engineering technology students and the rigor of program that eliminates the less able indicates that students of low academic potential in other curricula probably would not be successful in bachelor's programs in engineering technology. A possible exception may be transfers from engineering curricula. Data from two institutions indicated that low achievers in the engineering program transferred in small numbers to the engineering technology program and most were successful in completing the technology program. However, transfers from all curricula represent only a small fraction of registrants in engineering technology. An exception, of course, is the rapidly growing number of transfers from junior college technical programs.

Student Interests

No statistical data were obtained that would measure the interest patterns of engineering technology students or differentiate their interests from engineering students. Both engineering and engineering technology educators stated that the technology student had a greater interest in "hardware" or equipment and consequently in laboratory and technical skills. However, it appears that it will take especially knowledgeable and competent high school counselors to differentiate between potential engineering and engineering technology students. At the moment, aptitude in science, and especially mathematics, appears to be a more reliable indicator than interest patterns in machines, structures or electronics.

Laboratory Equipment and Other Facilities

No adequate data were found that would permit meaningful comparisons of laboratory equipment and facilities between various kinds of technology programs or between technology and engineering or physical science programs. Square feet of laboratory space, value of equipment, and other data usually submitted as part of the evaluation for accreditation vary so widely from institution to institution even for similar programs as to be essentially useless.

A qualitative evaluation of the technology laboratories visited indicated that, in general, they were oriented more toward production or testing than toward research or experimentation. Because of the need to develop technical skills, there frequently are extensive production or shop laboratories and large drafting rooms. With commercially manufactured laboratory equipment becoming increasingly available, there appears to be a small trend toward more standard experimental or demonstration laboratories in technology programs.

Placement of Graduates

While educators struggle with precise definitions and descriptions of educational programs, employers and employees in industry and professional practice apparently see engineering as a wide spectrum of activities encompassing a wide range of positions. The 1960 census recorded over three-quarters of a million persons who classified their occupation as engineer even though more than one-third of them had only a high school education or less. Similarly, employers classify many positions as engineering positions although the incumbents are not engineering graduates.

A number of institutions were requested to furnish the titles of positions offered to their baccalaureate engineering technology graduates. About three-quarters of the graduates were offered a position with the word "engineer" in the title. Examples of titles were junior engineer, engineer trainee, sales engineer, customer engineer, maintenance engineer, and manufacturing engineer.

Essentially the same titles are used by industry for engineering technology graduates as for engineering graduates for beginning jobs. An examination of the titles of positions offered hundreds of baccalaureate graduates from a number of institutions did not disclose a single title using the words "technician" or "technologist."

Strengths and Weaknesses

Engineering technology baccalaureate programs are of such recent origin that many parents, high school teachers and counselors doubtless are still unfamiliar with these programs. Nevertheless, enrollments are increasing even at institutions where engineering enrollment is essentially static. For established baccalaureate engineering technology programs, reports of annual increases in enrollment of 10 percent are not unusual and some of the newer programs report even more rapid growth. The Engineering Manpower Commission survey of technology degrees reported 264 graduates with bachelor's degrees in engineering technology from 17 schools in 1965-66; 842 graduates from 29 schools in 1967-68; and 2858 graduates from 65 schools in 1968-69. Undoubtedly some portion of the dramatic increase in both graduates and institutions is due to a more complete response to the survey.

Similarly, the reports from placement offices indicate that graduates are in demand by employers at salaries approximately \$50-\$75 less per month than bachelor degree graduates in engineering. Again, not many recruiters are aware of these programs, their graduates and their capabilities. Nevertheless, it appears that baccalaureate engineering technology graduates are finding a productive place in industry and in support of engineering practice.

One possible potential weakness of currently accredited engineering technology programs is the lack of breadth in technical science. As explained earlier, the objective of making graduates immediately useful upon employment conflicts with the objective of having graduates with a high degree of transferability to many jobs and a low degree of obsolescence. The heritage of vocational education with its objective of specific job training may have exerted influence on technology programs. However, the current rapid changes in productive processes, construction techniques, machines and methods used in industry--and consequently in duties of technological jobs--make it desirable to include greater breadth in technical science for those programs designated "engineering technology".

SECTION 9

CHARACTERISTICS OF BACCALAUREATE ENGINEERING TECHNOLOGY PROGRAMS

Goals and Objectives

The overall educational objective of engineering technology education is stated in Section 5 as follows:

> Engineering technology education is designed to educate two-year, associate-degree engineering technicians and four-year, bachelor-degree engineering technologists either to assist engineers or to provide independently the support for engineering activities...

The technologist with a baccalaureate degree receive a more intensive education than the technician in his technical specialty, an education of more breadth because of the two additional years, and of greater depth made possible by additional courses in mathematics and technical sciences. He is capable of independent action in performance of technical activities and is, therefore, frequently found in supervisory positions over technicians and draftsmen. His background in general or liberal studies equips him for positions in technical sales and other positions in which skill in public contacts is desirable. The engineering technologist performs many of the same kinds of activities as the engineer but at a different level.

The engineering technology educational program has the same elements as the engineering educational program: mathematics, basic science, technical science, technical specialty and related technical studies, communications and socio-humanistic courses. The essential curriculum content, mathematics and basic and technical science, is not of the same level, rigor or depth as in engineering. Therefore, only the activities in the field of engineering (including design) that do not require a sophisticated math-science background can be performed independently by the technologist. This is the thought that lies behind the statement "to assist engineers or to provide independently the support for engineering activities."

Characteristics of Baccalaureate Engineering Technology Curricula

The engineering technology study has not progressed far enough for a definitive recommendation to be made of the most desirable curricular subdivisions beyond the rough subdivisions of Figure 3 (see page 45). These subdivisions were based upon the industrial survey of the CSC Study of 1970 and the McCallick Report of 1966; the figure contrasts ET and IT modal curricula. It is recognized, however, that some fields of engineering technology, electronics for example, are more demanding than others in the math-

science and technical science areas. Such ET programs may not achieve the desirable breadth represented by 30 percent of non-technical content as shown in Figure 3. To achieve the technical objectives of such specialized baccalaureate technology programs, the following approximate allocations by curricular area appear reasonable:

Specialized Technology Program Curricular Areas		Approximate Time Allocation in Academic Years
Mathematics, Basic Science, Technical Science, Technical Specialty, and Related Technical Studies		3
Mathematics	1/2	
Basic Science	1/3	
Technical Science, Technical Specialty, and Related Technical Studies	2	
Communications, Humanities and Social Science		1

The approximate one-half academic year of mathematics should include college algebra, trigonometry and selected topics in analytic geometry and calculus. Other courses in mathematics, statistics, or computers may be included when needed to strengthen the foundation for subsequent technical subjects.

The approximate one-third academic year of physics and chemistry or other natural sciences should be at a level consistent with the objectives of the program. The study of these basic sciences should add to the foundation for subsequent technical courses, especially if quantitative emphasis is used.

Approximately two years may be devoted to the technical sciences, technical specialty and related technical studies. The technical sciences, like the engineering sciences, have their roots in mathematics and the basic sciences. They should provide the avenue for understanding the theoretical characteristics and properties of devices, systems, structures, and processes, as well as the appropriate methods of analysis. They should *not* be limited to those having a specific relevance to a particular technical specialty. The technical specialty courses and courses that support the technical major should enable the graduate to interpret, in practical terms, the results of engineering analysis and/or design. They should be up-to-date in the current state of the art in a particular technology. They should provide a basis for the graduate to distinguish between sound and unsound practice.

The approximately one academic year devoted to the areas of communications, humanities, and social sciences should reflect, and be consistent with, the

institution's general educational objectives. Within this allocation, a limited sequence of management-related courses may be included. However, the objective of breadth is compromised if such courses are themselves essentially technical.

To qualify as a baccalaureate curriculum, at least one-third of all the courses in the curriculum, including courses in the technical specialty, should be upper division courses. Upper division (third and fourth year) courses are generally those which require either lower division (first and second year) courses as prerequisites, or the mastery of a body of knowledge necessary to understand and successfully complete the upper division courses.

It is recommended that the degree designation for the curricula include the term "engineering technology" although it is clearly recognized that curricula with other names and degree designations may meet or exceed the recommended minimums and be a part of the family of engineering technology educational programs.

Admissions

The admission requirements for entry into the baccalaureate engineering technology curricula at either freshman or junior-transfer level should not be lower than the general admission requirements to the college or university of which the technology program is a part. Technology students should have the experience of competing successfully with other university students in mathematics, basic science, communications and socio-humanistic subjects.

Because the beginning mathematics course in an engineering technology curriculum is college algebra, the entering student should demonstrate proficiency gained by high school study of algebra and plane geometry for a total of at least two years as a prerequisite for enrollment in this program. Credit earned in remedial study should not be used to fulfill the criteria for an acceptable engineering technology curriculum.

High school courses in chemistry or physics, while not generally required for entering technology students, are highly recommended.

Faculty

It is axiomatic that faculty members should know more about the subject matter they are teaching than the students are expected to learn. This is self-evident for courses in communications, socio-humanistic subjects, mathematics and basic science. Technical sciences, the technical specialty and related technical courses-- drawing as they do on mathematics and basic science-- require faculty members who have mastered mathematics through rigorous courses in differential and integral calculus, who have a comprehensive knowledge of fundamental science and technical science based on this higher level of mathematics, and who have an advanced knowledge of their technical specialty acquired both by advanced study and relevant experience. It is recommended that

one-half of the faculty teaching the technical sciences, technical specialties, and related technical studies should have at least one degree in engineering or engineering technology in order to teach their subjects with the added dimension of demonstrating technological relationships to engineering activities. Further, because technologists are expected to be immediately useful to their employers, all faculty members teaching the technical specialty courses are expected to have had sufficient recent and relevant professional experience to train the student in the current practices and requirements of industry.

Faculty members teaching the technical skill courses are not required to have advanced degrees but are expected to be artisans or masters of their crafts.

Engineering technology education, with its emphasis on problem courses, participation laboratories and technical skills, requires a sufficient number of faculty to provide adequate attention to each student. The student-faculty ratio for technical courses will vary, depending on the nature of the curricula and courses, but should not exceed about fifteen to one. Student-faculty ratios for mathematics, basic science, communications, and socio-humanistic courses should follow the institutional pattern because most of these are courses offered to students majoring in many disciplines.

Supporting Facilities

It is particularly important that instruction in engineering technology be conducted in an atmosphere of realism. Theory courses should be strong in problem identification and solution, with emphasis on the quantitative, analytical approach. They should be accompanied by coordinated laboratory experiences, including the measurement, collection, analysis, interpretation and presentation of data. Laboratory equipment should include types that would be encountered in industry and practice. Since one of the objectives of engineering technology curricula is the development of technical skills, each student should be thoroughly familiar with the use and operation of the analytical equipment common to his major field of study. An experience in the operation of standard or basic shop equipment--lathes, welders, engines--does not alone meet this requirement.

Equipment catalogs, trade magazines, and journals of industrial processes and practices should be readily accessible and used by the technology student in addition to the usual library resources. The student should be familiar with the literature of his technology and encouraged to use it as the principal means of staying abreast of the state of the art in his technological field.

The computer has become one of the most important and versatile tools in engineering practice. The technologist as a part of the engineering team must acquire an understanding of its capacities and limitations in his field

of technology, and should develop some facility in its use for solving problems. Technology students should have access to digital computer equipment, and use computers to acquire the knowledge and skills described here.

The baccalaureate engineering technologist is not expected to require a long period of training by his employer before becoming a useful member of the engineering team. Therefore, his education must be conducted in appropriate classrooms, laboratories and other physical facilities by a faculty adequately experienced in practice and supported by non-academic personnel.

SECTION 10

PRACTICAL ENGINEERING *VERSUS* ENGINEERING TECHNOLOGY PROGRAMS

The advent of four-year baccalaureate curricula in engineering technology has led individuals and technical societies to express concern over the scientific orientation of modern engineering curricula. Without attempting to review history we may refer the reader to the ASEE report of 1955 on Evaluation of Engineering Education and the ASEE Goals Report of 1968 both of which recognized the need for a strong mathematics and science background in a modern engineering curriculum. In fact, one would have to consider curricula in use before 1920 to find examples that failed to include a rigorous study of mathematics through calculus, classical physics, and chemistry, which in total represented at that time about one-fifth of the curriculum. The math-science percentage now seems to have grown to about one quarter of four-year engineering curricula in response to the increased sophistication and extent of modern science and technology.

For a period of several years before and after 1960 the need for additional mathematics and science in engineering education was accomplished largely by lengthening curricula until they demanded more nearly five years of study than four. The recent trend to reduce curriculum length to a realistic four years without loss of mathematics and science background has squeezed the practice-oriented courses for the bachelor's degree down. It remains to be seen whether future master's degrees in engineering will provide additional training in design practice. These evolutionary changes in engineering curricula have been accompanied by the development of baccalaureate curricula in engineering technology and other technology.

Practical Engineering Curricula

There have always been some engineering curricula that diverge from the norm by placing increased emphasis upon engineering practice at the expense of either math-science or humanistic-social studies. Such curricula have not been particularly popular with students. In fact, over many years the most theoretical or mathematical curricula, electrical or electronic engineering, have had the highest enrollment of students; and a recent wave of popularity has produced rather large enrollments in systems engineering, another mathematically-oriented curriculum. Also, students press for admission to engineering colleges that are highly science oriented. The thought, therefore, that practical orientation of certain engineering department curricula might attract a new wave of students is not backed by previous experience.

The inherent problem is a tacit understanding of long duration that a rigorous study of calculus, physics and engineering science represents a minimum essential for the education of every engineer. The number of high school graduates who prepare themselves with the full set of preprequisites for engineering study and who are equally prepared for the rigor of such study by commitment to become engineering professionals is limited. The group may be divided between several engineering departments and/or subdivided between theory and practice, but the total number of enrolled students in engineering seems unlikely to be influenced significantly. On the other hand, the reduced math-science requirements in college along with reduced high school math-science prerequisites, acceptable for the study of engineering technology, opens up a much larger pool of high school graduates as possible registrants. There is no reason, therefore, for concern that the growth of technology programs may seriously reduce enrollments in engineering.

Transferability of Knowledge

The industrial interest in practical engineering graduates, who will be immediately useful upon employment, conflicts with the objective of making the years in college as productive as possible in terms of training that will have a low degree of obsolescence. Mathematics, English, basic science, engineering science and analysis have a high degree of transferability to many jobs and a low degree of obsolescence. It seems likely that these characteristics will continue to be emphasized by a large majority of engineering colleges. In contrast, technological curricula are designed for greater specialization and immediate usefulness of the graduates. The cost of specialization is reduced transferability from field to field and the probability of earlier obsolescence unless continuing education occurs.

There is an inevitable trade-off between transferability of knowledge and immediate usefulness in employment. Among industry's needs for all kinds of well-educated technical manpower, broadly trained engineers and specialized engineering technologists represent related but distinctly different educational products. It is not possible for one type of baccalaureate engineering curriculum or branches of a single curriculum to serve the contrasting objectives of scientific breadth and technical specialization. The Advisory Committee of the Engineering Technology Education Study therefore has concluded that, although some baccalaureate engineering curricula reorganized to place increased emphasis upon practice might serve a limited or specialized usefulness, the much greater need is for graduates of engineering technology programs at both the associate and baccalaureate degree levels.

SECTION 11

HUMAN SOURCE MATERIAL FOR ENGINEERING TECHNOLOGY EDUCATION

General Patterns of College Attendance

Currently, approximately 68% of American young men in the 18-24 age cohort may be expected to attend a college or other post-secondary educational institution. Typical data are as follows: 40% enter a four-year college; 12%, a two-year college; 3%, a technical institute; 1%, a business college; 4%, a trade or apprentice school; and 8%, an armed forces school (Flanagan, 1966). The proportion of students in technology programs is relatively small. Estimates are that only about 100,000 of the 4,400,000 males enrolled in higher education programs are studying engineering technology or related subjects. This is only 2.3% of the cohort. Moreover, about 20-30% of all students in higher education (and more in technical programs) drop out, so that fewer than 2% of the college age group graduate with specific education as technicians.

Career Preferences Expressed by High-School Males

High school senior boys, when asked to express a preference for a career do not usually give engineering technology a high priority; in one study (Flanagan, 1964) responses included the following expressions of choice:

Career	Percentage Preferring Career
Accountant	4.4
Biologist	1.6
College Professor	.7
Engineer	18.2
High School Teacher	4.6
Lawyer	4.1
Physical Scientist	3.5
Business Man	5.7
Physician	3.0
Craftsman	1.1
Engineering or Scientific Aide	1.0
Farmer	3.9
Skilled Worker	6.2
Structural Worker	1.5

The expressed preference for "Engineer" is remarkable. It is doubtless considered a professional or prestige title.

It is interesting to note that a substantial proportion (48%) of high school boys tend to plan careers in professional or technical fields, even though manpower utilization studies indicate that only 15% of employed males in the 25-29 year age group work in such fields. Accordingly, because of the rigor of the educational program and other factors, it appears that about

one-third of the high school graduates who so aspire attain planned careers for which a technical or professional education is necessary.

Characteristics of Students in Technical Programs

It is revealing to study the distribution of socioeconomic level and academic ability level of students who recently were enrolled in technical programs. Table 6 displays the data, where entries in the table are the percentages of the total male cohort belonging to each cell. For example, 5.3% of all males in the upper half of the socioeconomic spectrum and in the lower half of the ability spectrum attended a technical institute.

TABLE 6.--Distribution by Socioeconomic/Ability Cells of Males Enrolled in Technical Institutes[a]

	Lower Half, Ability Level	Upper Half, Ability Level
Lower Half, Socioeconomic Level	2.5	2.3
Upper Half, Socioeconomic Level	5.3	1.7

[a]Adapted from *Project TALENT One-Year Follow-up Studies* (Flanagan, 1966).

It is also interesting to compare four kinds of scientific-technical workers (i.e., research scientists, engineers, technicians, other technical workers) with each other and with other occupational groups. A possible result is the identification of traits most likely to be associated with individuals in various occupational areas.

The four categories of technological workers just mentioned have certain characteristics in common which distinguish them from the population as a whole. For example, they all score high on tests of visual reasoning, they are somewhat less interested than the "average person" in business matters, they display marked interest in outdoor or shop-related activities, they have a significant lack of cultural interests, and--predictably--their "science interest" scores on psychological tests exceed the population mean by at least one standard deviation.

The factor which seems best to discriminate between these four groups of technological workers is, predictably, mathematics aptitude and achievement. Research scientists have for this factor a group mean which is 3.4

standard deviations above the population as a whole, at the 99.9 percentile level. Engineers score at the 98 percentile level, technicians at the 82 percentile level, and other technical workers only slightly above 50, the population mean. Verbal aptitude is also a discriminating factor. Research scientists and engineers score at about one standard deviation above the mean. Technicians score at the mean, unschooled technical workers below it. "Sociability"--an indicator of interest in people, organizations, and group activities--is another interesting discriminant; both research scientists and engineers score below the population mean on this trait, while technicians and other workers score at the mean.

Observations

Consideration of the historical patterns of college attendance, typical patterns of career aspirations, and general characteristics of students in technical programs leads to the following observations regarding human source material which may have relevance to educators in the domain of engineering technology programs:

1. Normal selective admissions policies in educational institutions may eliminate many individuals who might succeed in engineering technology programs at the associate-degree level and highly selective admissions policies may eliminate potential students for the baccalaureate technology programs. Potential students for associate-degree programs may appear not to be "academically inclined", often coming from the lower half of their classes. Sufficient data are lacking on a minimum acceptable level of previous achievement for potential baccalaureate-degree students of engineering technology.

2. Students are apt to be disinterested in English and sociocultural matters; great skill must be used to introduce such vitally needed subjects into the curriculum in such a way that they are accepted by students as important to their future careers.

3. Because research scientists, engineers and technicians have similar attributes in all but a few areas, the counseling task is extremely difficult.

4. Career aspirations of boys tend to fall in technical areas; routes to satisfy such aspirations at levels socially acceptable should exist in order to capitalize on such motivations.

The High-School Pool of Technical Interest and Talent

As the mathematical (or theory) demands of science and engineering education have risen over the past decade and a half, the percentage of college students majoring in these fields has steadily declined. When it became clear that attractive careers could be had in social fields where the requirement for a rigorous study of mathematics and physics was nonexistent, an increasing percentage of students has passed up the hard sciences and engineering. Efforts to recruit more students into science and engineering

during the upper high school years have been unavailing. A recent survey published in the *Journal of Chemical Education* (Snelling and Boruch, 1970) clarified the fact that close to one-half of students who choose to major in science in college have made that basic decision before entering the ninth grade and over three-quarters had so decided before entering grade eleven. It seems likely that the general interest in a scientifically-oriented career *versus* one less technical is developed in pre-high-school years.

It is the belief of the staff of the Engineering Technology Education Study that the rigorous study of calculus followed by the equally rigorous courses in physics required of engineering students represent a barrier to increased enrollments that can and should be lowered for engineering technology students. The work of the technologist is usually not sufficiently involved with science and engineering theory to require more than an introductory problem-oriented approach to calculus. This limitation in itself will also limit the rigor of the physics course to well below that of engineering physics. The result should be to attract students who find practical applications of science intriguing but who have not prepared themselves for admission to engineering study. This pool of students may be as large as the potential engineers.

The Influence of Market Demand

Market demand for students graduating in a particular specialty within a field such as engineering or engineering technology may influence the choice of specialty by students. However, market demand at the time of baccalaureate graduation is displaced by six to eight years from the junior high school years when choice of broad field of employment along with decision to prepare therefor may be made. Hence the current demand for baccalaureate graduates in a broad field such as engineering technology has little effect upon the number of students selecting the field itself. Further, students who have committed themselves to a field as early as junior high school are unlikely to change that commitment because of reduced demand or current increase in demand in another broad field.

SECTION 12

CONCLUSIONS INDICATED BY INITIAL STUDIES

1. Manpower Trends and Projections

There is a need in engineering practice, industry and government for technicians and technologists at several educational levels, ranging from high school to baccalaureate graduates. Based upon Bureau of Labor Statistics data of 1966, it is estimated that of approximately one million technicians now employed, about two-thirds perform work related to engineering activities. However, only a quarter seem to have as much as two years of post-high-school education directed toward their employment. A large number of technicians (estimated at 1,200,000) will be sought by industry, government and other employers between 1966 and 1980. Their education is expected to be increasingly a function of the public junior, community and technical colleges.

2. Transition from Use of Engineers to Technologists

The extent of the need for graduates of baccalaureate engineering technology programs will not be well determined until a constant flow of engineering technologists becomes available to employers. The present production is almost insignificant and is often absorbed locally. The need for engineering technologists did not appear when young engineers were available for work at the technologist level. However, enhanced demand for engineers over the past decade, coupled with relatively fixed supply, made it necessary to utilize engineering graduates for the growing number of positions in planning, design, research and development at the level that can be performed only by engineers. Increasingly, positions in production, construction, operations, sales and services, formerly performed by engineering graduates, are being opened to engineering technologists. We have learned by necessity that such functions can be separated in large measure from creative engineering planning and design, and can be performed by engineering technicians and technologists.

3. Accreditation of Associate-Degree Engineering Technology Programs

The accreditation by ECPD of associate-degree engineering technician programs has assured employers that graduates have received an education of standardized content of an acceptable level and quality. Industry has recognized this attainment by ready employment of the graduates. Only a few junior college technician programs have applied for and received ECPD accreditation. If industry makes clear its preference for the graduates of ECPD accredited programs, it is believed that the administrations of an increasing number of junior college programs at the associate-degree level will aspire

to ECPD accreditation as engineering technology. In many cases major curricular changes and employment of faculty with engineering degrees will be required, but others may have anticipated the requirements of ECPD accreditation. The Advisory Committee is concerned that a large percentage of junior college technical programs have not as yet shown an interest in ECPD accreditation.

4. Anticipated Need for and Development of Engineering Technology Programs

It seems reasonable to assume that industry's efficiency would be improved sufficiently by post-high-school education of its technicians to justify employment of one-half with associate degrees and one-quarter with baccalaureate degrees. For one-half of the associate-degree engineering technicians to be graduated from institutions having ECPD accredited programs would require a four fold increase in the number of graduates and many new accredited curricula. For one-quarter of the technicians employed by industry to be employed eventually as graduates of baccalaureate-degree programs, and therefore to justify classification as technologists, would require a new educational development more than one-third as extensive as the present operation of engineering colleges. The magnitude of the educational tasks indicated at both the associate and the baccalaureate levels does not lead to great optimism that they will be achieved within a decade. Technicians will still have to be obtained by upgrading craftsmen despite the hidden costs of inefficiency and failure to make technical improvements that might otherwise be achieved.

5. Shortening the Time Period for ET Educational Development

In order to shorten the time period until a large fraction of technicians will have been provided with a formal education as outlined in the preceding statement, effort is needed to increase understanding and interest of high school students in a technological career, to upgrade to ECPD standards the quality of programs and teachers in additional technical institutes and junior colleges, and to encourage the development of baccalaureate ET programs in institutions of high standards as an example to others. A gradual development of new ET programs year by year is to be preferred to a crash development with accompanying minimal standards. The field of technology education has been plagued by extremely variable quality standards. New educational programs should be of uniformly good quality at the level of ECPD accreditation to assure that graduates can perform the technological occupations for which they have been educated.

6. The Central Objective of ET Education: Focus on a Material Result

The central objective of engineering technology education is support for the practical side of engineering achievement with emphasis upon the end product rather than the conceptual process. There are overlapping areas but, in broad outline, the engineering technologist may be said to achieve what the engineer conceives. The technologist is often a coordinator, the engineer is more often a planner. The technologist is valued as an expediter, the engineer is sought as an expert. The technologist should be a master of detail, the engineer of the total system. Hence we may characterize engineering technology education as follows:

> In contrast to engineering education where capacity to design is the central objective, engineering technology education develops capacity to achieve a material result based upon an engineering concept or design either through direct assistance to an engineer, in supervision of technically productive personnel, or in other ways.

Where the work of the technologist and the engineer are similar in kind they may be expected to differ in level because of the difference in level of their math-science and engineering science backgrounds. The development of new methods is the mark of the engineer; effective use of established methods is the mark of the technologist.

7. Essential Content of Engineering Technology Curricula of Any Length

Engineering technology education by definition must be more intimately related to engineering education than are other technological education programs that also build upon mathematics and the physical sciences. The engineering technician and technologist must therefore understand the language of engineering--written, symbolic and graphic--and he must be able to interpret in material terms engineering analysis and design. The essential content of engineering technology curricula--independent of length--must therefore be mathematics, basic science and technical science to a level consistent with this objective along with technical skills related to the use of equipment. Also, communication skills require attention. General or liberal studies should be included in appropriate relation to the length of the program. A limited study of management may be included to enhance opportunity for advancement, but it is not an essential characteristic of an engineering technology curriculum.

8. Differences Between Engineering and ET Baccalaureate Programs

Engineering technology curricula generally require one or two years less preparation in high school mathematics and a lesser science background than do engineering curricula. Engineering technology students normally terminate college-level studies of mathematics and science at a lower level than engineers. Less rigorous courses may also be provided. Hence in the technical science and technical specialty subjects, professors teaching technology cannot probe to the same depth in theory as engineering professors but must give greater emphasis through laboratory and skill courses to established methodology and practice. These variations are quite adequate to differentiate between the education of the engineering technologist and the engineer, but they are enhanced by the backgrounds and interests of the separate faculties. Engineering faculties are composed of a high percentage of engineering doctorates with research capabilities while engineering technology faculties, desirably composed of about one-half engineers, have fewer advanced degrees but include a much higher proportion of teachers with extensive industrial or other practical experience.

9. Curricular Differences Between Engineering Technology and Other Technology Programs

Engineering technology education must also be differentiated for purposes of accreditation from other technology programs. Although some diversified technology programs, usually termed industrial technology, may approach and later achieve accreditation as engineering technology, their more common formulation is of a different character, often described as broad rather than specialized. The mathematical content of many four-year industrial technology curricula may be terminated without any study of the calculus. The basic science requirement may be less and there are likely to be few, if any, technical science courses. The main thrust of such a program can be only indirectly related to scientific or engineering theory. Instead, it is usually pointed toward familiarizing students with methods, machines, skills and techniques of production or construction, and it always emphasizes industrial or personnel management. Considerable attention may be given to drafting as a means of technical communication. Nevertheless, the median for math-science-technical content of IT curricula is usually only about 50%, leaving an equal emphasis upon non-technical studies including business and management which form an important distinguishing feature. In contrast, the median for math-science-technical content of ET baccalaureate curricula is approximately 70%, leaving 30% for non-technical, mainly communication and liberal studies, with only limited time available for management courses. The math-science-technical content is found to be about 80% of two-year ECPD-accredited ET programs and also of four-year engineering curricula.

10. Possible Development of Practice Oriented Engineering Curricula

Some engineering educators appear to be considering a sub-division of engineering curricula (scientific *versus* practice orientation) as a means of attracting students into engineering who might otherwise enroll in engineering technology. The main block to increased engineering enrollments is a rigorous study of calculus, physics and engineering science, a minimum standard which dates back before 1920 for first-professional-degree students. It seems doubtful that lower standards could be accepted by ECPD or would have an appeal to engineering faculties. Without changed standards, larger enrollments are unlikely and costs would increase with increased curricular options. It is concluded, therefore, that the main source to satisfy the need for engineering technologists probably will not develop through options or subdivision of engineering curricula.

11. Educational Values: Obsolescence and Transferability of Knowledge

The Advisory Committee wishes to call attention to the long-term *versus* short-term value of different kinds of acquired knowledge. The objective of making graduates immediately useful upon employment conflicts with the objective of preparing graduates who will have a low degree of obsolescence. Mathematics, English, basic science, engineering or technical science, analysis and synthesis have a high degree of transferability to many jobs and a low degree of obsolescence. The cost of specialization is reduced transferability from field to field and the probability of earlier obsolescence unless continuing education occurs. Faculties must take this fact into consideration whether their objective is to educate engineers, engineering technologists or industrial technologists. The employer should evaluate this factor in relation to his employment policy and his program for continuing education of technical personnel.

12. Administration of Engineering Technology Educational Programs

The position of baccalaureate engineering technology in the educational administrative structure is as yet indeterminate. It appears that associate-degree programs will continue in the technical institutes but that growth in the number of two-year programs and increased enrollments are more likely to occur in the public junior, community and technical colleges. Some technical institutes will expand their programs to four years, often on a two-plus-two basis providing two points of logical termination. A few universities that receive a flow of junior college transfers have initiated two-year upper-division baccalaureate programs of engineering technology to accommodate associate-degree graduates from surrounding junior colleges. Industrially related, or co-op programs also exist. Some universities have initiated four-year programs of engineering technology under the administration of a college of technology. In others, ET programs are offered by an existing college of engineering and administered by its dean. It seems desirable to encourage all types of organizational experimentation although it is anticipated that one or two patterns will eventually prove most effective in the education of baccalaureate engineering technologists.

SECTION 13

STATISTICAL INFORMATION AND DATA TABLES

The following tables give reasonably current data and statistics that have relevance to the ASEE Study of Engineering Technology Education. The subjects covered are enrollments and projections, associate degrees and bachelors degrees for engineering technology and industrial technology, technicians employed by industry, hiring goals, salaries and job openings.

TABLE 7.--Reports and Projections of Enrollment in Institutions of Higher Education in the United States, 1960-75.[a]

Year (Fall)	Total	Degree Programs[b]	Non-Degree Programs[c]
1960	3,789,000	3,583,000	206,000
1963	4,766,000	4,495,000	271,000
1966	6,390,000	5,885,000	505,000
1969	7,541,000	6,906,000	635,000
1972	8,686,000	7,925,000	760,000
1975	9,956,000	9,056,000	901,000

[a]Adapted from Table 4 *Projections of Educational Statistics to 1977-78*, U.S. Department of Health, Education and Welfare, Office of Education, National Center for Educational Statistics (Washington: U.S. Government Printing Office, 1969).

[b]Includes all programs leading to baccalaureate or higher degree.

[c]Includes programs of occupational nature, wherein credits are not chiefly transferable to a baccalaureate degree and which are 3 years or less in length.

TABLE 8.--Reports and Projections of Earned Bachelor's and First Professional Degrees in the United States, 1960-75[a]

Academic Year (ending)	Total Degrees	Degrees in Physical Science and Related Areas[b]	Degrees in Engineering[c]	Percentages of Total	
				Physical Science	Engineering
1960	392,440	29,512	37,808	7.5	9.6
1963	447,622	34,752	33,458	7.8	7.5
1966	551,040	39,764	35,815	7.2	6.5
1969	749,000	60,130	39,972	8.0	5.4
1972	785,000	68,670	40,360	8.8	5.1
1975	898,000	85,170	40,690	9.5	4.5

[a]Adapted from Tables 18 and 20A, *Projections of Educational Statistics to 1977-78*, U.S. Department of Health, Education and Welfare, Office of Education, National Center for Educational Statistics (Washington: U.S. Government Printing Offive, 1969).

[b]Includes mathematics, statistics, computer science, astronomy, chemistry, earch sciences, meteorolgy, physics, and certain general science programs; excludes the biological sciences, agriculture, forestry, and the health professions.

[c]Data for 1960-69 from the Engineering Manpower Commission; see John D. Alden, "Engineering Degrees, 1968-69," *Engineering Education*, January 1970.

TABLE 9.--Associate Degrees in Engineering Technology Reported by Institutions Having at Least One Curriculum Accredited by ECPD[a]

Year	Number of Degrees Reported
1953-54	3927
1954-55	4365
1955-56	5499
1956-57	No data available
1957-58	5928
1958-59	6478
1969-60	7639
1960-61	6284
1961-62	6035
1962-63	5489
1963-64	5507
1964-65	5695
1965-66	5270
1966-67	6144
1967-68	6264
1968-69	6552

[a]Source: John D. Alden, "Technology Degrees, 1968-69, *Engineering Education*, January, 1970; see Table 1, p.410.

TABLE 10.--Degrees Awarded in Engineering Technology and Industrial Technology, 1968-69, By Curricular Area and By Level[a]

Area	Associate Degrees	Bachelor's Degrees
Aerospace	562	220
Agricultural	21	0
Architectural/Building	599	0
Chemical	395	133
Civil	1747	151
Drafting and Design	1359	122
Electrical/Electronics	8251	646
Industrial Engr. Technology	641	143
Mechanical	3315	410
Materials	83	7
Other Engr. Technology	1433	79
Industrial Technology	402	947
TOTAL	18808	2858

[a]Adapted from John D. Alden, "Technology Degrees, 1968-69," *Engineering Education*, January, 1970; see Table 2, p.411.

TABLE 11.--Ratio of Technicians to Engineers by Industry as Reported in 1968 by a Sample of 658 Employers[a]

Industry	Number of Technicians Employed by Respondents	Number of Technicians per 100 Engineers
Aerospace	8,306	28
Chemical	1,077	9
Construction	629	68
Consulting	2,505	58
Electrical/Electronics	6,960	69
Machinery	2,821	46
Metals	1,886	71
Other Manufacturing	6,260	38
Petroleum	435	51
R & D	5,368	68
Transportation	306	65
Utilities	4,863	66
Federal Government	2,200	41
State Government	18,332	161
Local Government	1,683	70
Education	1,345	20
All Respondents	64,976	54

[a]Adapted from Table 11, p.20, *Demand for Engineers and Technicians, 1968*, Engineering Manpower Commission of the Engineers Joint Council, December, 1969.

TABLE 12.--Comparison of Hiring Goals for Technicians and Number Hired, 1967-68, Reported by 852 Employers[a]

Category	Hiring Goal	Actual Hires	Shortage In Percent
4-Year Technology Graduates	323	168	48%
2-Year Technical School Grad.	3,187	2,519	20%
Other School Sources	1,473	1,338	9%
Experienced Technicians	2,885	2,571	11%
Newly Upgraded Technicians	878	870	1%
Trainees	2,647	2,556	3%

[a]Adapted from Table 17, p.27, *Demand for Engineers and Technicians, 1968*, Engineering Manpower Commission of the Engineers Joint Council, December, 1969.

TABLE 13.--Comparison of Hires, 1967-68, and Planned New Hires for Technicians, 1968-69, By 897 Employers[a]

Category	Hired in 1967-68	Planned for 1968-69	Planned Increase
4-Year Technology Graduates	231	342	48%
2-Year Technical School Grad.	2,482	3,269	32%
Other School Sources	1,750	1,979	13%
Experienced Technicians	3,127	3,505	12%
Newly Upgraded Technicians	1,311	1,372	4%
Trainees	2,878	3,045	6%

[a]Adapted from Table 17, p.27 *Demand for Engineers and Technicians, 1968*, Engineering Manpower Commission of the Engineers Joint Council, December, 1969.

TABLE 14.--Salaries for Technicians in 1969, All United States, by Educational Level and Years since Entering Work Force[a]

Years Since Graduation[b]	Mean Annual Salary		
	All Technicians[c]	Associate Degree	Bachelor's Degree
0	$6650	$ 7100	$8350
2	7100	7650	8650
4	7500	8150	9850
6	7950	8650	9200
8	8350	9050	9450
10	8750	9450	9650
12	9200	9850	10150
20	9850	10300	10300

[a]Adapted from "General Salary Curves," pp.18-20, *Salaries of Engineering Technicians, 1969*, Engineering Manpower Commission of the Engineers Joint Council, March, 1970.

[b]Base year is 1969. For Associate Degree recipients and non-graduates, this is considered age 20; for baccalaureate graduates, the equivalent age is 22. Year 0 represents initial salary.

[c]Includes all technicians, those with no prior formal schooling and those with educational background other than technology as well as graduate technicians.

TABLE 15.--Employment of Selected Professional and Technical Personnel Employed by Reasons of Nation's Development Goals, 1966, with Projection to 1975[a]

Item	Engineers	Natural Science and Engineering Technicians
Employed in 1966	1,116,000	713,000
Projected Employment in 1975, Assuming "Low" National Priorities[b]	1,589,000	1,518,000
Projected Employment in 1975, Assuming "High" National Priorities[c]	2,031,000	1,794,000
Proportionate Increase 1966 - 75, "Low" National Priority[b]	42%	113%
Proportionate Increase, 1966-75, "High" National Priority[c]	82%	152%

[a]Adapted from Table 1, Paul G. Larkin and John B. Teeple, "National Employment Goals and Higher Education," *College and University Business*, October-December, 1969.

[b]"Low" national priorities imply a continuation of the employment demands of the past decade and reflects national goals which are "more of the same" as existed in the 1960's.

[c]"High" national priorities imply bolder specific objectives and an enhanced pattern of technological and economic growth which could come about if national commitments are made to pollution control, urban redevelopment, space exploration, and other massive projects.

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APPENDIX A

TECHNICIAN MANPOWER, 1966-80: A Summary of Bulletin 1639, BLS

The Division of Manpower and Occupational Outlook of the Bureau of Labor Statisitics issued, in March of 1970, a bulletin which provides some insights into the factors affecting the supply and demand for technicians.

Highlights

More than one million new technicians (1,034,000) will be required to meet manpower requirements resulting from employment growth and replacement needs between 1966 and 1980:

--- 509,000 technicians will be needed for growth a 57% increase from the 900,000 employed in 1966 to the 1.4 million projected for 1980.

--- 525,000 technicians will be needed to replace those who die, retire or transfer to other occupations.

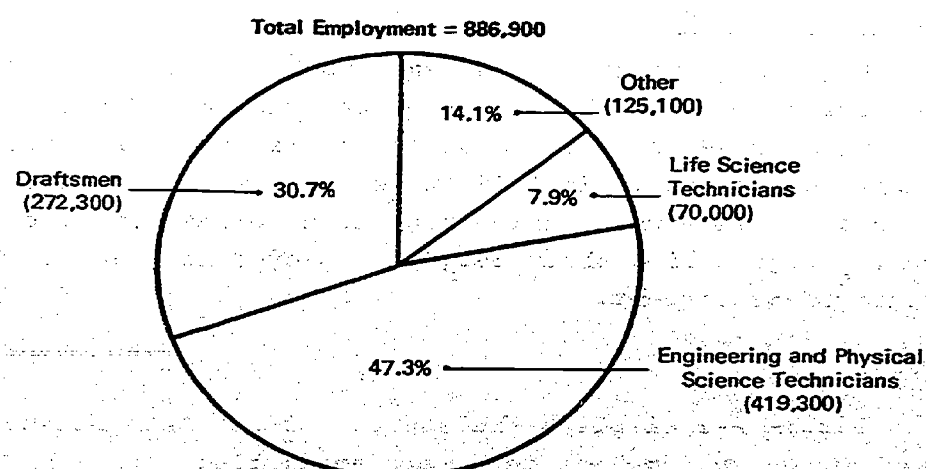
--- Requirements for engineering technicians are expected to increase by 50%; draftsmen by 60%.

--- While requirements for technicians in manufacturing are projected to increase at the average rate, the rates will be greater for machinery (87%) and electrical equipment (74%).

Employment, 1966

Nearly 900,000 engineering and science technicians were employed in the United States in 1966. Figure A-1 and the accompanying table give detailed data.

FIGURE A-1.-- ESTIMATED EMPLOYMENT OF TECHNICIANS, BY OCCUPATION, 1966



Note: Because of rounding, sums of individual items may not equal totals.
Source: Bureau of Labor Statistics.

TABLE A-1.--Employment of Technicians by Occupational Specialty, Estimated 1966 and Projected 1980 Requirements.

Occupation	1966 employment	Project 1980 requirements	Percent increase, 1966-80
Technicians, all occupations	886,900	1,395,700	57.4
Draftsmen	272,300	434,300	59.5
Engineering and physical science technicians	419,300	646,800	54.3
Engineering technicians	299,200	453,800	51.7
Chemical technicians	60,500	96,500	59.5
Physics technicians	10,600	20,700	95.3
Mathematics technicians	5,300	10,100	90.6
Other physical science technicians	43,900	65,700	49.7
Life science technicians	70,000	108,900	55.6
Other technicians	125,100	205,800	64.5

NOTE: Because of rounding, sums of individual items may not equal totals.

In 1966, more than 40 percent of all technicians were employed in manufacturing. Significant numbers also worked in private nonmanufacturing industries: 100,000 technicians were employed in engineering and architectural services; 40,000 in miscellaneous business services; and 32,000 in the communications industry. Nearly 165,000 technicians were government employees, mainly in the Federal Government. Colleges and universities employed about 32,000 and some 6,500 worked for nonprofit organizations. Almost one-half of engineering and physical science technicians were concentrated in manufacturing and reflected the large number employed in electrical equipment (64,000) and chemical industries (24,000).

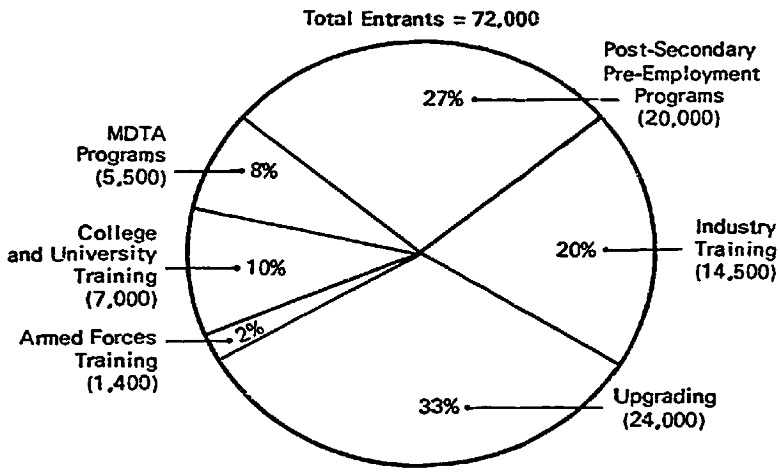
Employment Trends

An average annual employment growth of about 4 percent is projected for technicians. It is not expected that the ratio of technicians to scientists and engineers--one of the most common measures of technician utilization--will change appreciably. In 1966, this ratio was 63 technicians for each 100 scientists and engineers. Engineering technicians, the largest specialty, are expected to grow from about 300,000 employed in 1966 to 450,000 in 1980, an increase of 52 percent.

Supply

Figure A-2 displays the sources of new technicians in 1965, the last year for which complete data were available.

FIGURE A-2.--New Technicians, by Source of Training, 1965



Note: Because of rounding, sums of individual items may not equal totals.
Source: Bureau of Labor Statistics

Meeting Manpower Needs

Approximately one million technicians (1,034,000) will be required over the 1966-80 period to meet manpower needs for employment growth and worker replacement. If all past trends, evident in 1965 and supported by later data, should continue, 1.2 million workers can be expected to enter technician jobs from preemployment and technician-related training between 1966 and 1980. The following estimates have been made by BLS:

Source of New Technicians 1966-1980	Number
Post secondary Preemployment Training	750,000
Employer Training	175,000
MDTA Training	95,000
College (4-year) graduates and drop-outs	150,000
Armed Forces Training	21,500
TOTAL	1,191,500

However, losses from separation and transfer are to be expected; thus, only about 935,000 of these new entrants will probably remain in the field in 1980. It appears, therefore, that preemployment training programs along cannot supply all the technician manpower needed and that an additional 120,000 technicians will have to be upgraded to obtain a net of 99,000 technicians to meet total manpower needs of 1,034,000 in 1980. Upgradings of this magnitude -uld approximate only 10 percent of all entrants for the period, clearly a vast provement in the technician manpower situation.

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